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on the Ozone Layer
Fifth Session

Copenhagen, 12-16 October 1981

REPORT OF THE FIFTH SESSION

Na.81-1434

I. OPENING OF THE MEETING

1. The meeting was opened at 10.00 a.m. on 12 October 1981 by the Danish Minister for the Environment, Mr. Holst, at the Government meetings reception rooms, Udenrigsministeriet, Asiatisk Plads 2, Copenhagen. In his address, Mr. Holst welcomed participants to Copenhagen and expressed pleasure in being asked to open the meeting. He said that Denmark considered it her duty to contribute to the continued efforts to seek solutions to environmental problems, such as depletion of the ozone layer. He considered it right, that the initial work of preparing a global framework convention for the protection of the ozone layer should be based upon contributions from the Co-ordinating Committee on the Ozone Layer, where technical knowledge was concentrated. Mr. Holst pointed out that discussions at the international level must be followed up at the national level, and he gave a brief account of Denmark's own legislation and actions in this field. The Minister concluded by expressing a wish that the sessions debate should be fruitful, and that the Committee's traditionally constructive discussions would continue as before.

2. Dr. Francesco Sella, the Acting Assistant Executive Director, replied to Mr. Holst's address on behalf of the Executive Director of UNEP. Dr. Sella congratulated the Danish authorities for the considerable organizational effort they had devoted to the preparation of the meeting and at the same time welcomed them as the newest full member of the Committee. Dr. Sella urged caution and conservation in the use of chemicals that may affect the ozone layer in view of the agreement that some measure of change would occur even though it was at present impossible to quantify the change with confidence. In referring to decision 9/13B which called for the initiation of work aimed at the elaboration of a global framework convention, Dr. Sella said that the value of a convention involving technical issues relies heavily on the quality of the technical input, thus a heavy responsibility was placed on the Committee's deliberations. Dr. Sella drew attention to other important issues. In particular, information needs for the compiling of technical data concerning production and release of chloroflourocarbons and the socio-economic aspects of predicted ozone layer depletions.

3. Mr. Rudolf Engelmann, the Chairman of the CCOL then addressed the meeting and echoed Dr. Sella's concern for the necessity to prepare within the CCOL a strong contribution to the scheduled ad hoc Legal/Technical Group Meeting. Mr. Engelmann then introduced the provisional agenda and gave a brief explanation of the items included and the issues involved.

II. DOCUMENTATION

4. A list of documentation before the Committee is reproduced in Annex 1.

III. AGENDA

5. The following agenda was adopted:

1. Opening of the meeting.
2. Approval of the Agenda
3. Recent research results and ongoing and planned research programmes and activities relevant to the World Plan of Action on the Ozone Layer.
   UV-B mapping.
4. Assessment of ozone depletion and its impacts.
   Ozone depletion scenarios.
5. Need for revision of the World Plan of Action on the Ozone Layer.
6. Decision 9/13B of 26 May 1981 on the 9th Governing Council of UNEP.
7. Ozone depleting chemicals other than chlorofluorocarbons 11 and 12.
8. Recommendations for action.
9. Any other business.
10. Executive Summary/Press Release
11. Approval of the report.
12. Closure of the meeting.

IV. PARTICIPANTS AT THE MEETING

6. The meeting was attended by experts designated by the following countries, United Nations bodies and specialized agencies and non-governmental organizations.

Governments: Canada, Denmark, Federal Republic of Germany, France, Italy, Japan, Netherlands, Norway, Sweden, Union of Soviet Socialist Republics, United Kingdom of Great Britain and Northern Ireland, and the United States of America. Switzerland attended the meeting as an observer.

United Nations bodies and specialized agencies:
World Health Organization, World Meteorological Organization and the United Nations Environment Programme.

Inter-governmental Organizations: European Economic Communities and Organization for Economic Co-operation and Development.

Non-governmental Organizations: Chemical Manufacturers Association.

A full list of the participants is given in Annex 2.

V. REVIEW OF RECENT RESEARCH RESULTS AND ONGOING AND PLANNED PROGRAMMES RELEVANT TO THE WORLD PLAN OF ACTION ON THE OZONE LAYER

7. Presentation made by members on these subjects are given in Annex 3. Also under this agenda item, a report on UV-B mapping was presented to the Committee by Dr. H. Wiser of the United States of America.

VI. ASSESSMENT OF OZONE LAYER DEPLETION AND ITS IMPACTS

8. The Committee formed three working groups to develop an assessment of ozone layer depletion and its impacts. Working group Chairmen were elected by the Committee as follows:

Measurements and Trends	Dr. R.D. Bojkov World Meteorological Organization

Chemistry and models	Dr. A.E.J. Eggleton and Dr. R.G. Derwent United Kingdom
Effects	Dr. J.C. Van der Leun Netherlands and Professor Dr. M. Tevini Federal Republic of Germany

The reports of the three working groups were considered by the Committee and a concensus was agreed on a current assessment of the problem which appears below.

VII. ASSESSMENT OF OZONE LAYER DEPLETION AND ITS IMPACTS, OCTOBER 1981

OZONE OBSERVATIONS

9. The ultimate test of the ozone depletion theory depends on the detection of long term changes in global total as well as vertical, ozone distribution, which in turn requires a continuous and comprehensive flow of reliable data from the ozone observing system. Ground-based measurements form an important element of the system, both on their own account and by providing the ground truth data for satellite-based systems, which can provide more comprehensive information on both total and vertical ozone distribution. However, good ozone measurements are difficult to make, and their interpretation subject to many uncertainties (e.g. long-term instrumental drift) and high natural variability (e.g. synoptic, seasonal, solar, etc.).

10. Total ozone: During the past six years about fifty Dobson ozone-spectrophotometers were upgraded and/or intercompared with either the world primary standard instrument located at NOAA-Boulder, Colorado, USA, or a regional (secondary) standard instrument. Most of the Dobson ozone data reported to the World Ozone Data Center (WODC) - Toronto, are obtained from these instruments. The importance of these intercomparisons is reflected in the calibration errors discovered which have been more than 7 percent in a few instances. Although shown by only a few instruments, these differences indicate the existence of stations generating data at times with large errors. The presision of a well kept Dobson instrument network is estimated to be ±1.5% for calculations of global annual means. However, the accuracy of the network could be considerably worse due to the uncertainty of the absorption coefficients. Drifting of instrument readings was also demonstrated, and frequent (once in three to four years) intercomparisons are therefore considered essential.

11. There is still room for improvement in the data obtained from the ground-based total ozone network - both in quantity and quality. There is spatially uneven distribution of the stations - about two thirds of the total number of stations are located between 30°N and 60°N. More even distribution, frequent instrumental checks and increased regularity of observations could have a positive effect on the quality of the data.

12. Approximately one third of the existing ground-based stations do not report regularly to the World Ozone Data Center - Toronto, and therefore could not be used in trend analyses. Of the number regularly reporting, a significant fraction (~ 20%) provides data derived from lower quality filter instruments. The International Ozone Commission has concluded that the performance characteristics of another instrument (the Brewer spectrophotometer) meet all observational requirements, will not distort the homogeneity of the network, and therefore has recommended its inclusion in the ozone measuring network, supplementing or possibly replacing some ot the Dobson instruments.

13. Vertical Ozone Distribution: The predicted percentage depletion of the ozone concentration at upper stratospheric levels due to CFC releases is calculated to be several times greater than the corresponding predicted depletion of the total ozone amount. Thus data from this level should provide the most sensitive information for ozone perturbations. This strongly supports the need of vertical ozone distribution data.

14. So far,ground-based Umkehr measurements represent the largest set of data for vertical ozone distribution. This set is especially useful for analysis of the 25 to 50 km region in the apmosphere. However, only about a dozen stations make them regularly. Recently a new "short Umkehr" multi-wavelength method has been developed and should be widely encouraged. Direct measurements by balloon-borne sondes are needed for more detailed analyses of vertical ozone distribution, circulation studies etc. The network of ozone-sondes are known to be inadequate as less than a dozen stations make weekly balloon ozone soundings and only a few have continuous records longer than ten years. International intercomparisons of various types of operational ozone-sondes have been conducted twice,in 1970 and 1978/80. Other comparisons are planned for 1982. Efforts should be directed toward the continuation and improving of balloon ozone-sondes in parallel with the increase of indirect measurements of vertical ozone distribution by, for example, the Umkehr method.

15. Satellite Measurements: The past ten years have seen the development of several satellite-borne instruments for measurements of both the total column and vertical distribution of ozone using a variety of experimental techniques. The instruments that have, or are, currently being used to measure:

(i) total column ozone - are based on the techniques of Solar Backscattered Ultra-Violet (BUV,SBUV/TOMS) and Infra-Red radiance in the 9.6 μm band (IRIS, MFR, HIRS-2). The data which have been processed and validated are proving to be most valuable. There is a systematic difference between near simultaneous BUV and Dobson total ozone observations, the Dobsons being at the average about 7 percent higher.

(ii) vertical ozone distribution - are based on the same basic techniques as for total column ozone, i.e. Solar Backscattered Ultra-Violet (BUV, SBUV) and Infra-Red radiance in the 9.6 μm band (LRIR, LIMS). In addition, the technique of solar occulation in the visible region has been used (SAGE). The BUV data and part of the SBUV are now available; the data from other satellite instruments are now being validated and processed.

16. In future years satellite systems will play an increasing role in the monitoring of ozone. Supported by Umkehr measurements, they provide the best means for early detection of anthropogenic influences on the ozone layer in the upper stratosphere. Present satellite systems should continue to be supported in parallel with efforts to improve their accuracy and reliability.

17. Rocket-borne ozone-sondes: Rocket-borne measurements are necessary mainly for satellite instrument calibration. About sixty recent inter-comparative flights should enable an assessment to be made of data derived from previous rocket soundings and is expected to improve our knowledge of the upper stratospheric ozone distribution.

18. Global Ozone Observing System (GOOS): Careful assessment of the performance characteristics of the various ozone observing systems concluded that a continuous flow of reliable, total and vertical ozone data forming a coherent set could be achieved by integrating the ozone observing systems using the satellite-borne observing systems and a set of well maintained ground-based stations. In order to achieve full integration there is a strong need for intercomparisons of routine by used ozone-sondes with different research type sondes in order to clear up certain remaining discrepancies in the 30-35 km region.

OZONE DATA ANALYSIS

19. The relatively large natural variability of atmospheric ozone makes detection of trends difficult. The ground-based Dobson network indicates that between 1965 and 1980 several periods of increases and decreases have occured with ranges of one to several percent changes, each lasting several years. There exist indications of a possible solar cycle variation which is yet difficult to assert with any statistical certainty. There is no evidence of an overall change of greater than 2% in total ozone between 1958 and 1980. More refined statistical analyses of data from 36 select Dobson stations confirms this finding and shows no evidence of a statistically significant trend in the period 1970 to 1979.

20. Total ozone measurements from the backscattered ultraviolet (BUV) Nimbus-4 satellite so far analysed for limited period, show a time-varying discrepancy with data from the Dobson network. It is presumed that there has been a drift in the satellite measurements. Without correcting this apparent drift, the satellite indicates about a 1% greater ozone decrease between 1970 and 1974 than does the Dobson network. The attempt to correct for the drift results in essentially no change in satellite-derived ozone amount between 1970 and 1974, in comparison with the Dobson decrease of nearly 2%. In future, because of the excellent spatial coverage of a satellite system, proper intercalibration with the Dobson network should permit a considerable improvement in global total ozone values. It is estimated that the mean monthly global total ozone value so obtained should be in error by no more than 1 percent.

21. Any potential influence on ozone amount caused by chlorocarbons should be most apparent near 40 km, at a height where photochemistry dominates transport effects. It is as yet uncertain to what extent the Umkehr derived 10% increase in the 32-48 km layer in North temperate latitudes between 1965 and 1970 is real (possibly due to the tendency for a greater ozone amount at sunspot maximum) and to what extent it is artificial, caused by the effect on the Umkehr method, of aerosols injected into the stratosphere at the time of the eruption of Mt. Agung (1963) and their subsequent decrease. In the same layer (32-48 km) there was an appreciable (about 4%) decrease indicated immediately following the

Mt. Fuego eruption in 1974. The ozone concentration in this layer by 1979/80 had slowly reached the same value as in 1973/74. A study of data for 32-48 km layer from 12 Umkehr stations in the northern hemisphere, over the period 1970-79, indicates that no statistically significant change could be detected. Satellite data from same altitude layer when published should provide additional information which need to be interpreted carefully.

22. There is a discrepancy between Umkehr-derived and ozone-sonde-derived ozone trends in the 16-32 km layer of North temperate latitudes, the Umkehr measurements indicating essentially no change in ozone amount between 1970 and 1979, the ozone-sondes an ozone decrease of a few percent. Thus, in this layer we cannot be sure of the actual ozone variation.

23. In the 2-8 km (tropospheric) layer the ozone-sondes indicate an approximate 20% increase in ozone between 1967 and 1980 in North temperate latitudes. A similar increase in North polar latitudes makes it unlikely that this increase is due to local sources of urban photochemical pollution in the troposphere. Thus, the ozone-sonde data suggest that the near invariance in total ozone in the last decade has been associated with a partial balance between the possible stratospheric ozone decrease and indicated tropospheric ozone increase.

OZONE TREND DETECTION

24. With reference to the question: How well can we establish the effects of man-induced activity on any change in total ozone? it is recognized that, even though a reasonably accurate determination of the global total ozone can be obtained, is does not mean that anthropogenic effects can be easily detected. The key issue is the relatively large natural variability in total ozone. With a data record of only about twenty years it is not possible to specify with confidence this natural variability. Consequently, anthropogenic influences, with the possibility of additional simultaneous positive and negative effects of different origin, cannot easily be delineated even by sophisticated statistical techniques at this time.

25. It was noted that the estimate of total ozone change determined recently in three studies was a statistically nonsignificant increase of 1 percent for the period 1970-79 with an uncertainty averaging ± 1.5 percent. The error limits (95% confidence limits) reflect the natural, spatial and instrumental uncertainties that are revealed in the analysed data.

26. Such recent developments in statistical methods show that at present, a trend attributable to combined anthropogenic sources in the total ozone of 2% change since 1970, is the smallest that could be detected by the Dobson monitoring network. However, on meteorological considerations, taking into account possible influences and effects unrevealed by the statistical analyses, the threshold may be as high as 4 percent. As the data record becomes longer, this statistical analysis for the detection of trends may improve its precision.

SOURCES AND SINKS OF CFC'S

27. World production of CFCs 11 and 12 combined as estimated by the Chemical Manufacturers Association (CMA) has fallen by a total of 18 percent between 1974 and 1980 from 851 Kt p.a. to 696 Kt p.a. (thousand metric tonnes). Most of the decrease occured in the years 1974 to 1977; only 1% decrease took place in the past year, please refer to data supplied by CMA for full details. These estimates are based on data supplied to the CMA by reporting companies with an estimated accuracy of 5% together with an uncertain 8% contribution from countries not reporting to the CMA. Data from non-reporting countries is needed in order to improve the accuracy of estimates of global production. The corresponding estimated releases of these CFCs have fallen from 741 Kt to 591 Kt between 1974 and 1980.

From the data of the reporting companies only, there has been a reduction in the annual combined use for aerosols and open cell foam (giving immediate atmospheric release) from 610 Kt to 350 Kt over the period 1974 to 1980 but an increase in the annual amount used in refrigeration and closed cell foams (delayed release) from 203 Kt to 290 Kt over the same period. It is recognized that eventually the reduction of CFC use in aerosols could be offset by growth in non-aerosol uses. This indicates the importance of monitoring all uses of CFCs 11 and 12.

28. Present model estimates of ozone depletion due to CFCs 11 and 12 allow for their destruction only in the stratosphere. The presence of a loss mechanism in the troposphere would cause a reduction in their overall lifetimes and a commensurate reduction in the resulting estimate of ozone depletion at steady state assuming continued release of CFCs at constant rates.

29. Atmospheric measurements of CFC-11 and CFC-12 have revealed a steady increase throughout the troposphere over the past decade. In principle, such measurements when taken with atmospheric release data, can be used to derive atmospheric lifetimes for CFC-11 and CFC-12 and hence determine whether there are significant tropospheric sinks. A network of five measurement stations has been set up in locations remote from significant CFC sources to acquire long-term data for CFC-11 and CFC-12 (together with carbon tetrachloride, methylchloroform, CFC-113 and nitrous oxide) using regular calibration with the specific objective of establishing atmospheric lifetimes. This objective should be achieved in a few years, but there will be a continuing need to maintain a global monitoring network of comparable quality for CFCs 11 and 12, together with other chlorocarbons for a much longer period to provide an independent check on release data. In addition, efforts seeking direct evidence for the existence of specific tropospheric sinks are continuing. At this time the available information is not sufficient to be properly evaluated.

30. No organisation currently collects global production data for halocarbons other than CFC 11 and 12, which may affect the ozone layer. Less extensive atmospheric data are available for these compounds of which the most significant are methyl chloroform (CH_3CCl_3), carbon tetrachloride (CCl_4) and CFC-113 ($CCl_2F\ CClF_2$), but there are a number of others which need to be considered in a full treatment. Based on approximate estimates of current production these substances would cause in the steady state an additional ozone depletion of about a third of that due to CFC-11 and CFC-12. However, the production of methyl chloroform and some others has grown substantially in the recent past, and there has been a corresponding increase in atmospheric concentrations though these data are rather fragmentary. If this growth were to continue while the production of CFC-11 and CFC-12 remains constant or declines, then these other compounds could assume an importance equal to that of CFC-11 and CFC-12 at some time in the future. Thus there is a clear need to acquire relevant global release data and to extend corresponding atmospheric measurements.

ATMOSPHERIC PHOTOCHEMISTRY

31. During the last few years considerable progress has been made in the laboratory measurement of rate coefficients, cross-sections, and primary quantum yields for use in atmospheric modelling. However, a number of problems remain, ranging from small differences in results for a given parameter obtained by different laboratories, to the possibility that major processes have not been incorporated into the photochemical model. The following discussion will emphasize the uncertainty in those processes which are not well defined, and for which the ozone perturbation calculations are sensitive, rater than discussing the large majority of processes for which the present data base is thought to be well established. Increased emphasis is currently being placed on understanding reaction mechanisms over the full range of atmospheric temperatures and pressures since the partial pressures of other gases such as water vapour, or oxygen, may occasionally affect reaction rates, and in addition, certain reactions may proceed via multiple reaction pathways.

32. The chemistry of the global troposphere is complex with both homogeneous and heterogeneous (for example rain-out) processes playing important roles. Significant progress has been made in understanding the coupling between the carbon/nitrogen/hydrogen/oxygen systems, and the details of the hydrocarbon oxidation mechanisms which play a vital role in controlling tropospheric hydroxyl radical concentrations. This is an important development insofar as the hydroxyl radical plays a central role in photochemically controlling ozone in the troposphere and controlling the tropospheric concentrations of gases such as CH_3Cl and CH_3CCl_3. In the context of stratospheric chlorine photochemistry (i.e. a coupled oxygen/nitrogen/hydrogen/chlorine system) it should be stressed that the basic formulation remains unchanged from that originally forwarded by Rowland and Molina in 1974, namely that there are no identified catalytic cycles involving chlorinated species which are thought to result in the production of odd oxygen. The numerous changes that have been made in estimates of certain rate coefficients have predominately involved temporary reservoirs such as ClO, HO_2NO_2, HNO_3, and $ClONO_2$. This has modified our understanding of the lower stratosphere, but not our basic perception of the role of ClO_x in the photochemically-controlled region above 30 km where temporary reservoirs such as HOCl and $ClONO_2$ play a far less significant role. In turn each chemical family is discussed below, although it is recognized that there is strong coupling between each of them.

33. Odd-Oxygen Reactions (O_x): The key photochemical processes involving O_x species only, are now considered to be well understood. Minor uncertainties still exist in certain processes but these uncertainties do not cause significant problems for stratospheric modelling.

34. Odd-Hydrogen Reactions (HO_x): The rate coefficients for reactions which control the abundance and partitioning between the odd-hydrogen radicals (OH and HO_2) are required with high accuracy due to the central role that the hydroxyl radical plays in controlling the catalytic efficiencies of both NO_x and ClO_x. Unfortunately, some of the largest uncertainties and most significant recent changes in rate coefficients fall within this category of reactions. Most simple OH reactions were, until quite recently, thought to be well established, however, recent work on $OH+H_2O_2$ and $OH+HNO_3$ has shown this belief to be incorrect. As was suggested in the last report the key reactions, $OH+HNO_3$, $OH+HO_2NO_2$, $OH+HO_2$ have been studied during the past year and this has led to a new balance among chemical catalytic cycles in the lower stratosphere. Understanding the reactivity of the HO_2 radical still remains one of the major problem areas in atmospheric photochemistry. However, while it is essential to understand the effect of H_2O vapour or HO_2 reactivity, it is important to recognize that such effects will be significantly more important for tropospheric and lower stratospheric than for upper stratospheric photochemistry. The question of pressure and temperature dependence of OH and HO_2 reactions continues to be important and requires extensive study especially in view of the unusual pressure dependence observed in certain reactions ($OH+CO$, HO_2+HO_2), and the unsual temperature dependence observed in others (HO_2+HO_2, HO_2+ClO, $OH+HNO_3$).

35. Odd-Nitrogen Reactions (NO_x): In general, the kinetic data base for NO_x reactions is relatively good. The major problem areas have already been outlined in the previous section (e.g. processes involving HNO_3 and HO_2NO_2). The decrease in HO_x concentrations in the lower stratosphere has significantly enhanced the role of odd nitrogen in this region. Additional studies of processes involving NO_3, N_2O_5 are required but are unlikely to have a major impact on modelling results.

36. Odd-Chlorine Reactions (ClO_x): The kinetic data base for ClO_x reactions has improved significantly in the last few years, but there are still several areas of concern. The problem of which isomers of $ClNO_3$ are formed in the $ClO+NO_2+M$ reactions, and what the dissociation products of these isomers could be, has still not been resolved. Recent changes in the

relative importance of ClO_x in the lower stratosphere have reduced the model-predicted influences of CFC's on ozone, particularly in the lower stratosphere. Last year's results on the temperature dependence for HOCl formation and the absorption cross section of HOCl coupled to the recent decrease in estimated HO_x concentrations in the lower stratosphere has considerably reduced the importance of HOCl.

37. Odd-Bromine Reactions (BrO_x): The lessened importance of ClO_x in the lower stratosphere has for all practical purposes eliminated any potential impact of BrO_x on ozone chemistry at current stratospheric concentrations.

CURRENT STATUS OF MODEL PREDICTIONS

38. Most predictions of stratospheric ozone depletion from man-made causes continue to rely on one-dimensional (1-D) models. The principal focus remains with the impact of continued release of CFC-11 and CFC-12 although there are many other factors which may influence the stratospheric ozone amount over a similar time scale. Ignoring all other potential changes, current predictions of the impact of continued release of CFC-12 and CFC-12 at the 1977 rate range from about 5 to 10 percent ozone depletion in steady state* compared with the value of 10 percent given at the UNEP Co-ordinating Committee on the Ozone Layer held in November 1980. This downward revision has been caused mostly by adjustments to the rate coefficients of the above mentioned HO_x reactions. This range merely reflects the uncertainty in our quantitative understanding of HO_x chemistry and transport parameterisations in the lower stratosphere. Other uncertainties which are not included directly in the above range are discussed in paragraphs 51-55 below. The estimate of the present total column ozone depletion due to CFC-11 and CFC-12 alone, has been similarly reduced and is less than 1 percent, which is below the present detection limit.

39. Two-dimensional model studies show that variations of the predicted ozone depletion with latitude and season are to be anticipated. The maximum reduction occurs in the late winter/early spring with a minimum in late summer/early autumn. There is a greater reduction at high

* Although "steady state" in the current sense is a mathematically well-defined situation, its physical meaning is simply the condition in the future when all relevant variations in time of all the parameters of interest have been reduced to a very low level. The length of time required in reaching such a condition differs greatly from scenario to scenario.(see para 52

latitudes than in the equatorial regions, with slightly more overall reduction in the northern hemisphere than in the southern hemisphere. The differences between mean reductions at low latitudes and high latitudes are qualitatively the same in all 2-D models although not identical quantitatively. The research community is still in the process of developing a full understanding of 2-D models. These latitudinal and seasonal variations have implications for changes in the intensity of UV-B radiation at the earth's surface as compared to the global average results of 1-D models. The 2-D model predicted global averaged changes are in good agreement with the corresponding estimates from 1-D models.

40. The predicted ozone reduction shows significant variations with altitude with the greatest percentage depletion of about 35% predicted to occur locally at about 40 km in steady state. The present-day estimated local ozone reduction around 40 km is expected to be around 4%. The recent changes in the HO_x chemistry have less effect on the percentage ozone reduction prediction in this region than in the lower stratosphere where the bulk of the ozone column resides.

41. Whether the models realistically forecast what is likely to happen in the stratosphere depends on the correctness and completeness of their input data and their coverage of the simultaneous effects of other atmospheric pollutants. It is not realistic to consider global ozone reductions in terms of releases of CFC-11 and CFC-12 alone. Many other factors may increase or decrease the global amount, and it is this combined effect which will determine what will actually happen to the ozone layer. A full study must take them all into account since they may interact together in a non-linear manner typical of a highly-coupled system. In addition to the natural perturbing effects such as lightning, volcanic eruptions, cosmic rays, solar proton events, global circulation changes and the variability of solar radiation, consideration should be given to:

(i) other man-made chlorine-containing compounds such as methyl chloroform, carbon tetrachloride and other chlorofluorocarbons, (CFC-113, CFC-114, CFC-115 and CFC-22). The potential for future growth in their atmospheric releases is more difficult to assess but estimates indicated that if releases continue at present levels then they could increase the steady state ozone depletion from CFC 11 and 12 alone by about one third. Most of this enhancement is derived from the release of CCl_4, CFC 113 and methyl chloroform, with minor contributions from CFCs 114, 115 and 22.

(ii) increased emissions of N_2O from the soil due to fertilizer application and changes in land use. Increases in atmospheric N_2O lead to an increase in stratospheric NO_x hence decreased ozone amounts. But with a hypothetical scenario leading to a doubling of N_2O with continuing present CFC release the net effect is not simply the linear sum of the individual impacts. This is due to the highly coupled nature of the basic catalytic cycles. With the recent changes in HO_x chemistry the estimated joint N_2O-CFC steady state depletion in total ozone is 9-17 percent while that for the doubling N_2O only scenario would be 8-16 percent, and the CFC 11-12 only scenario would be 5-10 percent.

(iii) increased atmospheric burdens of carbon dioxide (CO_2) could cause an increase in the stratospheric ozone amount through decreased stratospheric temperatures. Recent studies in both one-dimensional and two-dimensional models suggest that the effect of a hypothetical joint CFC-CO_2 scenario is to reduce the steady state total ozone depletion to between one half and three quarters of the value from CFCs 11 and 12 alone. In these joint scenario calculations, it was assumed that the atmospheric burden of CO_2 is eventually doubled with continued release of CFC 11 and 12 at 1977 production rates. Stratospheric and tropospheric temperature changes may also affect the H_2O amount in the stratosphere which in turn will change the abundance of HO_x. However, the theoretical basis for this is too uncertain to make good quantitative estimates.

(iv) emissions from aircraft and aerospace operations. The recent changes in the HO_x chemistry in acting to decrease the magnitude of CFC perturbations have, at the same time altered current understanding of the impact of stratosheric NO_x increases. Furthermore, NO_x emissions from subsonic aircraft, particularly in the middle and high latitudes of the northern hemisphere, may have noticeably increased the ozone content of the upper troposphere. Calculations indicate that large fleets of aircraft, whether supersonic or subsonic operating in or above lower stratospheric altitudes, would significantly deplete the ozone layer; that fleets operating exclusively below such altitudes would cause some ozone increases. Thus the ozone change attributable solely to existing or planned fleets would depend on their sizes and operating altitudes.

(v) increased CO and NO_x from combustion. Such emissions may not only increase tropospheric ozone but may also change tropospheric OH. Increased emissions from combustion may thereby influence the injection of CH_3Cl, CH_3CCl_3 and CH_4 into the stratosphere. At present, detailed information on the tropospheric budgets is inadequate to form a quantitative view.

(vi) past atmospheric nuclear tests. Although the available modelling results and observations on the total ozone trend in the 1960's are consistent, due to the widely accepted uncertainties, this apparent agreement is judged not to be conclusive. If the effects on the ozone layer due to past atmospheric nuclear testing were significant, then these past events may interfere with analysis of past ozone data for the detection of other possible influences up to this time. This is yet to be fully determined.

42. At present, we are a long way from developing consistent and realistic strategies for studying all the perturbations to the ozone layer. This adds considerable uncertainty to the predicted ozone changes. Nevertheless, one should note that with an hypothetical scenario using the historical release of CFCs 11 and 12 up to 1980 held constant thereafter, CO_2 doubling by 2050, 0.2% per year growth in N_2O concentrations and a subsonic aircraft fleet increasing by a factor of 10 between 1975 and 1990 held constant thereafter, a recent calculation shows less than a one half percent total ozone change during the next few decades in the northern hemisphere. The ozone concentration in mid-latitudes is predicted to decrease by as much as 40% at 40 km and to increase by as much as 25% at 10 km in steady state. This strong distortion of vertical ozone distribution may have a noticeable climatic impact which has yet to be analyzed.

42.a Refinement of one-dimensional model structure is rapidly approaching its useful limit. Two-dimensional models overcome some of the difficulties and inadquacies of 1-D models and reveal information on the seasonal and latitudinal dependence of ozone changes. A start has been made on the inclusion of dynamical feedbacks, and these may improve the quality of the predicted ozone changes. There have been a number of recent theoretical advances in two-dimensional modelling. As yet no new practical models have appeared based on these recent theoretical developments but the prospects for progress in this, so far insufficiently studied area, appear to be good.

COMPARISON OF THEORETICAL MODELS AND MEASUREMENTS OF THE ATMOSPHERIC TRACE SPECIES

43. The first and so far the only general test of the validity of any photochemical model is the accuracy with which it reproduces the trace gas distributions in today's atmosphere. Unfortunately, a conclusive comparison between model predicted and measured trace gas distributions is limited by several factors:

(i) Although much work continues to be done, the available data are still insufficient to fully characterize the spatial and temporal variations in the stratospheric distribution of the trace gases. Except for ozone, only scattered vertical profiles are available for most trace constituents. Some important species have not been measured at all.

(ii) Due to natural variability and sometimes to experimental uncertainties, the available measurements usually only define the atmospheric concentrations within a certain error range.

(iii) Most of the measurements represent local and instantaneous concentrations whereas the models calculate concentrations which are averaged over considerable spatial and time scales.

44. Despite these limitations, the comparisons form a reasonable test at least for 1-D models, since, in their totality, the measurements place rather narrow constraints on the range of concentration values which can be assumed by the model for the various trace gas species. The models have been generally successful in describing the average vertical trace gas distributions in the stratosphere. This is especially true for some long-lived trace gases such as CH_4, N_2O, CF_2Cl_2, H_2, where the globally-averaged features are quite well described by 1-D models. With the recent availability of profiles of trace species from different latitudes, finer details may become apparent which will require multi-dimensional models for their interpretation. The existing data base is yet inadequate to provide a validation of multi-dimensional models.

45. For the short-lived species which are produced and destroyed within the stratosphere, the same situation does not generally prevail. Some measured species such as O, O_3, NO_3 and HCl show reasonable agreement

between model and measurement over the altitude range of interest. Recent changes in HO_x chemistry data have helped greatly in resolving past difficulties in comparing lower stratospheric NO_2 and ClO data. New upper stratospheric NO observations are also in much better agreement with model predictions. However, the upper stratospheric distributions of HNO_3 and ClO are still difficult to understand.

45.a. Recent measurements of light hydrocarbons in the lower stratosphere have led to some concern about the adequacy of our understanding of the chemical partitioning among the various chlorine species.

46. In summary, it appears that present models are fairly successful in reproducing most of the features of stratospheric photochemistry as represented by the limited observations. Recent interests in developing proper interpretations and diagnostic techniques for model and experiments are expected to result in a new class of atmospheric observations more directly interpretable which may hence serve as better tests of models, as for example, in the recent simultaneous measurements of NO_3, O_3 and temperature.

INTERPRETATION AND EVALUATION

47. Since all models are approximations to reality, it is essential that the unquantified assumptions governing the adopted approximations should be considered along with other readily quantified parameters. Uncertainties in measured solar flux intensity, chemical kinetics reaction rate coefficients, model boundary conditions, transport coefficients, source distributions, and others can, in principle, be evaluated. Although all these parameters are not known to similar degrees of accuracy, recent progress in analysis, techniques and measurement programmes promise steady improvements in the years to come. Present analysis of the uncertainties inherent in the model predictions can only be considered as the best available information. The unquantified uncertainties, such as the possibility of missing chemistry, the adequacies of 1-D, 2-D, or 3-D model transport formulations, diurnal, seasonal or spatial averaging procedures for the non-linear interactions and the adequacy of model validation procedures, by necessity, must be evaluated partly on a subjective basis.

48. Existing views of the model's ability to describe the present day atmosphere and predict potential perturbation span the range from a high level of confidence based on the positive results discussed in previous sections to strong reservations based on the still unquantified uncertainties. The subjective components in the interpretation of model predictions will most likely persist.

49. The complementary relationship among 1-D, 2-D, and 3-D models is widely accepted, and current information strongly supports this view. Recent results from two-dimensional models on stratospheric ozone perturbation studies serve to elaborate on the seasonal and latitudinal variations of the ozone change but have not significantly altered global average predictions based on 1-D models. In addition, multi-dimensional models have pointed to new coupling processes, most notably in the troposphere, that could not have been studied with 1-D models.

50. Difficulties in 1-D model validation persist in 2-D models. This has led to new interest in re-examining the question of whether the major chemical processes in the lower stratosphere have been included in the model. Developments to date may affect the model predictions on CFCs effect quantitatively but not qualitatively, i.e. CFC increase leads to a decrease in total ozone.

51. The two major aspects of model predictions, past or near term trend and steady state ozone change, have different sensitivities to model input parameters. In the analysis of possible trends, a major uncertainty lies in the transport parameters. Whereas for steady state changes, one additional concern is with the uncertainty of the future state of the atmosphere. Recent research interest in coupled perturbations from multiple causes has contributed a wide appreciation of the degree of complexity of this problem. Single isolated scenarios are inadequate in describing reality either past or future. Increased efforts must be devoted to assessing the most probable coupled scenarios based on world evolution in economics and culture patterns. Only model predictions based on such scenarios can be used to compare with ozone observations in testing the theory of ozone chemistry.

52. Present understanding of stratospheric ozone chemistry and transport still points to a principle of persisting effect of past emissions in stratospheric ozone perturbation. Namely, that if countermeasures were undertaken after observing a certain ozone change, the said effect would be likely persist for decades before recovery. Further, due to the

complexity of coupling among multiple perturbing influences it is difficult to provide general guidance for evaluating the possible persisting perturbing effects and its duration. The duration of perturbing influences could vary from a few years (aircraft NO_x perturbation) to several decades (CFC perturbation) to centuries (CO_2 and N_2O perturbations). Such evaluation of magnitude and duration must be performed on a case-by-case basis with the appropriate scenario.

53. A decrease in atmospheric ozone results in increased penetration to the earth's surface of the damaging short wavelength UV-B* radiation. The increase is non-linear and highly dependent on wavelength; it is the steepest for the shortest wavelengths in sunlight. Most action spectra considered in biological effects of UV, such as the DNA or erythemal or plant response action spectra, show that 290 nm photons are about four orders of magnitude more effective than 320 nm photons. Therefore, it is important to consider the radiation flux wavelength by wavelength over the entire UV-B spectrum.

54. Models have been developed which permit the quantitative weighting of increases in UV-B irradiance according to the various action spectra, taking into account variations in ozone column thickness, solar angle, aerosol thickness and surface albedo. The percentage change in the effective daily UV-B radiation dose produced by a one percent change in ozone column thickness is defined as the radiation amplification factor. Data shows that, in general, for biological action spectra commonly used by photobiologists, this radiation amplification factor varies from about 1.6 to about 3 for most latitudes and seasons, with the higher values existing near the polar regions.

BIOLOGICAL EFFECTS

55. If a depletion of atmospheric ozone does occur, the UV-B irradiance will increase in all areas of the world. This may have biological influences on plants, animals and man. Therefore, it is necessary to identify the biological effects to be expected and, if possible, to make quantitative assessments of these effects, especially with regard to agricultural production, fisheries and human health.

* UV-B 280-315 nm
UV-A 315-380 nm

56. Effects on terrestrial plants: Higher plants have obvious importance both in agriculture and in natural terrestrial ecosystems, such as forests. Plants have evolved to expose much of their living tissue to sunlight in order to utilize its energy. Thus, a reduction of total ozone, with its attendant increase in solar UV-B radiation, could be significant for them.

57. Studies have been conducted in growth chambers, adjusted to natural daylight rhythm, in greenhouses and in the field under conditions of enhanced UV-B radiation. In spite of the different growing conditions, but under similar illumination, similar results were obtained in plant species sensitive to UV-B. Damaging effects were seen to growth parameters, leaf surface structure, composition, physiological function, pollen germination and productivity of a large variety of plant species, including many important crops, such as wheat, rice, soybeans, barley, potatoes and beans. The enhanced UV-B exposure levels at which the harmful effects began to occur depend on the sensitivity of plant species and ranged from natural sunlight levels to 50 percent enhancement of UV-B radiation. Tests of more than 100 plant species and varieties in controlled-environment growth chambers indicate that approximately 20 percent are already sensitive to present daily UV-B doses at latitudes of about 30°N, 60 percent showed intermediate sensitivity, whereas 20 percent were resistant event to UV-B doses 4 times greater than normal.

Some experiments have shown that especially early stages of growth are sensitive to additional UV-B. It has also been observed over several growing seasons that under enhanced UV-B the competition behaviour of plant species is changed, depending on the composition of the plant communities.

58. The action spectra for most of the effects of ultraviolet radiation on plants are similar to the DNA and erythemal action spectra. The action spectrum for damage to photosynthetic activity, however, differs markedly from these. It is much less steep, showing a decrease of effectiveness by only a factor of 3 over the wavelength region from 280 to 340 nm, as compared to a factor of at least 1000 for most of the other action spectra over an even narrower wavelength range.

59. Non-damaging, but highly sensitive and specific UV-B effects on formations of secondary plant substances, which may act as natural protective agents, were found in many plants.

60. The environmental conditions under which many growth chamber experiments have been performed may in some cases have altered the sensitivity of plants to UV-B radiation. Before any firm conclusion can be drawn about effects on agricultural productivity, it will be necessary to conduct experiments simulating proper natural radiation conditions, both in the laboratory and in the field.

61. Effects on aquatic organisms: Solar UV-B radiations inducing biological effects have been measured to depths of more than twenty meters in clear waters and more than five meters in unclear water. Much marine life sensitive to these UV-radiation levels (fish eggs and larvae etc.), live in the top 20 meters of ocean waters. Experimental studies with enhanced UV-B levels from zero up to fifty percent above natural levels have shown effects to fish (eggs, larvae and juveniles), shrimp, crabs, zooplankton and other plants essential to the aquatic food web. In addition, phytoplankton studies in the laboratory show that increased growth occurs when the UV-B radiation is filtered out of the incident solar radiation, indicating that existing levels of UV-B depress productivity.

62. The relative sensitivities of seven species within a selected aquatic ecosystem, studied in the laboratory under enhanced UV-B resulted in shifts of community composition. These results were corroborated by a study in a natural marine ecosystem. Studies on over 60 aquatic micro-organisms, protozoa, algae and small invertebrates, that form the base of the food web of oceanic and estuarine ecosystems, indicate that most of these, too, are sensitive to current levels of UV-B radiation incident at the water surface. More recent and more quantitative studies indicate that at doses comparable to daily levels of existing natural UV-B radiation incident at the water surface, reduction of UV-B increases the growth of chain-forming diatoms, and similarly affects the biomass and specific diversity of attached marine algae and survival of coral reef epifauna. Under conditions of enhanced UV-B radiation, decreases were observed in growth, reproduction, survival and other functions of these organisms.

63. Continued investigations concerning the range of natural ecological uncertainties, which are much larger than the uncertainties in the particular photobiological effects, will be required to assess the possible consequences for the many complex ecological interactions as well as for the productivity of fisheries.

64. Effects on human health: Considerable progress has been achieved in the study of the human health effects of increased ultraviolet radiation. Human health is influenced by UV radiation in many ways, such as the formation of vitamin D_3, sunburn, eye diseases, allergic reactions, and skin diseases including skin cancer. Among these effects, skin cancer stands out as the one problem to be significantly influenced by inceased UV-B irradiance. The severity of health and other biological effects of radiation depend on its spectral composition, irradiance, and exposure time. The response may be modified by biological factors and environmental conditions. UV-B radiation has been demonstrated to be more biologically effective than UV-A radiation.

65. Epidemiologic studies have shown that the incidence of non-melanoma skin cancer correlates with exposure to sunlight; these data relate mainly tc lightskinned people. Animal experiments have revealed that UV-B is the most effective wavelength region in carcinogenesis by UV radiation. These data indicate that an increased incidence of non-melanoma skin cancer is to be expected in the case of increased UV-B irradiance.

Non-melanoma skin cancer is exceptional among the biologic effects under discussion, in that numerical statistics are available. This has made it possible to make comparatively developed quantitative extrapolations. These studies indicate that, besides the radiation amplification mentioned already, there is for this particular biologic effect also a biologic amplification; for every percent increase in effective UV-B irradiance, the incidence of non-melanoma skin cancer will ultimately increase by more than 2 percent.

66. There are several indications that sunlight may also be one of the causative factors in the pathogenesis of malignant melanoma, which affects people of all skin types. These indications come from epidemiologic observations which, because they deal with exposure to total sunlight, do not point to any particular wavelength range in the solar spectrum. Animal experiments indicating the effective wavelength range are not available.

Should UV-B be involved, a decrease of stratospheric ozone might be expected to increase the incidence of melanoma. This is a possibility, but it cannot be substantiated on the basis of the presently available data.

67. In studies performed on mice, UV-B radiation has been shown to alter the response of the immunological system; for instance, this results in impeded ability of the animal to reject a UV induced tumor as a foreign body, and in increased susceptibility of the animal to primary tumors induced by UV.

EFFECTS ON CLIMATE

68. Even if total ozone is not significantly changed the projected distortion of the vertical profile is expected to have climatological consequences. The projected CFC- and CO_2-effects on the temperature are additive. The indicated increase of ozone concentration in the troposphere would on the other hand through modification of the IR-flux lead to a temperature rise at the surface - also adding to surface heating effect of CO_2. Therefore, increased research efforts on these problems are thus urgently needed especially in the framework of the WMO-ICSU World Climate Research Program.

VIII. OZONE DEPLETION SCENARIOS

69. The representative of the Organization for Economic Co-operation and Development presented a report on ozone depletion scenarios being undertaken by that Organization. It was stated that during 1981, the OECD prepared a report on emissions scenarios for chlorocarbon releases. These scenarios, along with a single scenario for emissions of other materials affecting the ozone layer, were used as input to various one and two dimensional models of the atmosphere. The report, which includes a summary of the results of the modeling work and the discussion of that work at the meeting of an Ad Hoc Group which met in September, will be presented to the Environment Committee of the OECD in December 1981, who will determine what future work in this area will be carried out.

IX. NEED FOR REVISION OF THE WORLD PLAN OF ACTION ON THE OZONE LAYER

70. Document UNEP/CCOL/5/5 The World Plan of Action on the Ozone Layer was reviewed, so as to determine if the requirements of the plan were still valid and complete, whether it was sufficiently detailed and comprehensive, and whether all gaps in knowledge identified in the Plan were being actively filled and at a satisfactory rate of progress.

71. Many delegations, while stating awareness of inaccuracies in parts of the original plan, in the light of new knowledge available, felt that no changes should be made to the text, but instead emphasis should be placed on the requirement, contained in the Plan of Action, to implement and further develop the Plan.

72. Several delegations considered that the CCOL had been somewhat negligent in not addressing certain aspects of the Plan as thoroughly as other sections, particularly socio-economic aspects. However, several delegations cautioned that it would be difficult to widen the scope of current and past activities of the CCOL in view of the additional cost associated with enlarging their delegations to cope with a broader Agenda.

73. It was noted that no lead agency had been designated to undertake the implementation of this section unlike other sections and one delegation suggested that OECD would be the obvious choice for this. After support for this view was expressed by others, it was suggested that UNEP should contact the OECD Environment Committee with a view to soliciting their aid in this connection. Also, UNEP will, at the time of requiring members to furnish their annual report on ongoing and planned activities, request that a report on national socio-economic measures be included.

X. DECISION 9/13B OF 26 MAY OF THE 9TH GOVERNING COUNCIL OF UNEP

74. A general discussion was held to decide in which way the CCOL could best respond to the invitation of the Executive Director to contribute to the ad hoc working group of legal and technical experts planned for 20 to 29 January 1982 at Stockholm.

75. It was agreed that a small working group be established to consider this matter and to report to plenary session of the CCOL on completion of its deliberation. The report of the group is attached as Annex 4.

76. The Secretariat reported to the members on responses received from Governments to the Executive Director's letter of 21 July 1981 which requested information, including statistical and technical data, on the implementation of the recommendations contained in Decision 8/7B of 29 April 1980, in particular relating to the use of chlorofluorocarbons 11 and 12, as well as to production capacity. The Secretariat noted that thirteen replies had so far been received. The Committee was informed that a full report on this subject would be submitted to Governments in the Report of the Executive Director to the tenth session of the Governing Council in May 1982 and to the ad hoc Legal/Technical Group Meeting at Stockholm in January 1982.

XI. OZONE DEPLETING CHEMICALS OTHER THAN CHLOROFLUOROCARBONS 11 AND 12

77. The Committee recommended that the UNEP Secretariat should collect data on chemicals, other than CFC's 11 and 12, that might effect the stratospheric ozone layer. The more important of these chemicals are identified in Section VII. The assessment of ozone layer depletion and its impacts. The Secretariat was asked to report to the CCOL at its next session on the information received.

XII. RECOMMENDATIONS FOR ACTION

78. The Co-ordinating Committee on the Ozone Layer made specific recommendations for activities relevant to the implementation of the World Plan of Action on the Ozone Layer. These were:

1. to make the Global Ozone Observing System (GOOS) based on integration of satellite and ground-based systems fully operational, and appeal for regular reporting of observational data to the relevant world centers;

2. to request UNEP to continue its support for strengthening and catalysing international activities through the WMO Global Ozone Research and Monitoring Project;

3. to intensify upgrading and intercomparisons of Dobson instruments;

4. to expand vertical ozone distribution measurements by continued balloon-borne soundings and by widely implementing "short-Umkehr" measurements as well as by encouraging the development of reliable operational satellite sensor for accurate measurements over the complete altitude range of the stratosphere including the continued development of inflight calibrations;

5. to encourage measurements of trace species of importance to the ozone question;

6. to undertake simultaneous <u>in-situ</u> measurements of the relative concentrations of photochemically related compounds of the various families;

7. to promote systematic review (using log calibration records) for homogeniety of long total ozone records;

8. to call the attention of all countries who are not yet reporting production figures of CFC's 11 and 12 as well as of other chlorocarbons to the need for reporting pertinent chemical production, release and usage data;

9. to promote studies of radiative effect of ozone and other minor species relevant to ozone photochemistry and stratospheric dynamics for detecting possible climatic impact;

10. to promote studies aimed at clarifying physical processes and phenomena having impact on error detection of ozone records;

11. to request countries to give more attention to UV-B measurements, in principle in the vicinity of ozone measuring stations as it was noted that the UV-B measurements are so far only isolated national efforts which have not been internationally standardized and integrated;

12. to continue to develop multi-dimensional models and continue to study the simultaneous effects on the various species which may perturb atmospheric ozone;

13. to continue to develop tropospheric monitoring to assess the sources, sinks, trends in concentrations of CFC's 11 and 12, chlorocarbons, N_2O, and CH_4;

14. to intensify the ongoing research on the representation of transport processes for chemical models;

15. to extend the determination of rate coeficients over the pressure and temperature ranges found in the atmosphere, and identify the products;

16. to search for and investigate any additional reactions which may affect stratospheric chemistry;

17. to continue efforts to increase understanding of tropospheric chemistry;

18. to extend measurements of the radical species to the lower stratosphere and upper troposphere using independent techniques;

19. to obtain 3-D fields of important trace constituents and meteorological variables in the stratosphere by satellites;

20. to improve knowledge pertaining to:
    (i) the relationship of dose and dose-rate and response for the various biological effects of UV radiations;
    (ii) the relationship between human exposure to solar ultra-violet radiation and the development of non-melanoma, and to better define the possible relationship between sunlight and melanonia skin cancer including social and environmental conditions; as a result of these studies, global base-line data on skin cancer incidence should be established;
    (iii) the identification of high-risk groups among the populations;
    (iv) the possible interaction of chemicals, pharmaceuticals and pollutants with UV radiation.

21. to study biological effects of enhanced UV-B on agricultural crops in different geographical locations and under local growing conditions;

22. to extend aquatic effects studies to the natural water environments in order to gain knowledge of the resultant effect of enhanced sola UV-B radiation on aquatic food productivity;

23. to continue studies on biological action spectra and the spectral response using also polychromatic radiations in order to include possible interactions of the various wavelength regions;

24. to include photorepair, adaptation and protection mechanisms in the overall considerations of UV-B effects;

25. to determine the influence of existing and enhanced UV-B radiation on:
    (i) the sensitivity and activities of insects important to the biospheric balance (animal food chain, plant cross-fertilization, etc.);
    (ii) micro-organisms, such as those causing plant and animal diseases;
    (iii) primary processes such as photosynthesis, biosynthesis etc.;
    (iv) the photodegradation of herbicides, pesticides, fertilizers and similar agricultural chemicals;
    (v) the effects of other stress situations;

26. to determine the mechanisms by which UV-B radiation acts on biological species and eco-systems;

27. to promote the publishing of manuals providing guidelines for both UV-B exposure studies and to facilitate intercomparison of biological research results;

28. to develop improved individual and biological UV-B dosimeters.

XIII. ANY OTHER BUSINESS

79. It was requested that the Executive Director of UNEP should liaise with the heads of other Organizations with a view to co-ordinating UNEP activities on ozone with those activities of a similar nature being conducted by those others, leading to an efficient scheduling of meetings convenient to participants.

XIV. EXECUTIVE SUMMARY/PRESS RELEASE

80. An executive summary of the conclusions of the Co-ordinating Committee was prepared. The text of this document is reproduced as Annex 5.

XV. APPROVAL OF THE REPORT

81. The draft report of the meeting and its five annexes were approved unanimously by the members of the meeting.

XVI. CLOSURE OF THE MEETING

82. The Chairman of the Co-ordinating Committee on the Ozone Layer, Mr. R.J. Engelmann, in closing the meeting, paid tribute to the Government of Denmark for making the Committee so welcome in Copenhagen on the occasion of the fifth session of the CCOL. In particular, he thanked the Ministry of Foreign Affairs and the Ministry of the Environment and their hard-working staff who had contributed so much to the smooth running of the meeting. Addressing the chairman of the working groups, Mr. Engelmann, thanked them, and the members of their groups for addressing their most difficult task so ably and providing such a valuable contribution to the success of the session.

He wished participants a safe return home and looked forward to meeting with many of them, both at Stockholm at the ad hoc Legal/Technical Group meeting in January 1982 and at the sixth session of the CCOL.

83. The meeting closed at 3.30 p.m. on Friday 16 October 1981.

ANNEX 1

Co-ordinating Committee on the Ozone Layer
Fifth Session, Copenhagen, 12 - 16 October 1981

List of Documents

UNEP/CCOL/5/1	-	Provisional Agenda
UNEP/CCOL/5/2	-	Annotated Provisional Agenda
UNEP/CCOL/5/3	-	Ongoing and Planned Activities Relevant to the World Plan of Action on the Ozone Layer - Contribution by the World Meteorological Organization
UNEP/CCOL/5/3/Add.1	-	- do - Contribution by Italy
UNEP/CCOL/5/3/Add.2	-	- do - Contribution by India
UNEP/CCOL/5/3/Add.3	-	- do - Contribution by Canada
UNEP/CCOL/5/3/Add.4	-	- do - Contribution by United Kingdom
UNEP/CCOL/5/3/Add.5	-	- do - Contribution by Switzerland
UNEP/CCOL/5/3/Add.6	-	- do - Contribution by France
UNEP/CCOL/5/3/Add.7	-	- do - Contribution by Netherlands
UNEP/CCOL/5/3/Add.8	-	- do - Contribution by Japan
UNEP/CCOL/5/3/Add.9	-	- do - Contribution by Denmark
UNEP/CCOL/5/3/Add.10	-	- do - Contribution by Federal Republic of Germany
UNEP/CCOL/5/3/Add.11	-	- do - Contribution by the World Health Organization
UNEP/CCOL/5/3/Add.12	-	- do - Contribution by the Organization for Economic Co-ordination and Development
UNEP/CCOL/5/4		Summary by Recent Research Results - Contribution by the Chemical Manufacturers Association
UNEP/CCOL/5/4/Add.1	-	- do - Contribution by Switzerland
UNEP/CCOL/5/4/Add.2	-	- do - Contribution by Federal Republic of Germany

UNEP/CCOL/5/5	-	World Plan of Action on the Ozone Layer as adopted by the UNEP meeting of experts designated by Governments, Inter-governmental and Non-governmental Organizations on the Ozone Layer, Washington, D.C., 1-9 March 197
UNEP/CCOL/5/6	-	Decision 9/13B on the Governing Council of UNEP regarding Chlorofluorocarbons
UNEP/CCOL/5/6/Add.1	-	Decision 8/7B of the Governing Council of UNEP regarding Chlorofluorocarbons
UNEP/CCOL/5/6/Add.2	-	Definition of Production Capacity
UNEP/CCOL/5/7	-	Descussion Paper on Technical Aspects of a Draft Convention to Protect the Ozone Layer - Contribution by Sweden and Denmark
UNEP/CCOL/5/8	-	Planned workshops on the effects of UV-Radiation - Contribution by Federal Republic of Germany
UNEP/CCOL/5/9	-	1980 World Production and Sales of Fluorocarbons CFC-11 and CFC-12 - Contribution by the Chemical Manufacturers Association
UNEP/CCOL/5/Background 1	-	Report of the Fourth Session of the Co-ordinating Committee on the Ozone Layer
UNEP/CCOL/5/Background 2	-	The Chlorofluorocarbon Ozone Theory - Contribution by the Chemical Manufacturers Association
UNEP/CCOL/5/Background 3	-	Review Papers on the Effects of UV-B on non-human Biota - Contribution by the Chemical Manufacturers Association
UNEP/CCOL/5/Background 4	-	Systemic Influence of pre-irradiation of a limited skin area on UV-Tumorigerisis - Contribution by Netherlands
UNEP/CCOL/5/Background 5	-	Background Atmospheric Concentrations of Halogenated Hydrocarbons in Japan - Contribution by Japan
UNEP/CCOL/5/Background 6	-	Proposal for a council decision on the consolidation of precautionary measures concerning chlorofluorocarbons in the environment - Contribution by the European Economic Communities
UNEP/CCOL/5/Inf.1	-	Documentation
UNEP/CCOL/5/Inf.2	-	List of Participants

ANNEX 2

Co-ordinating Committee on the Ozone Layer
Fifth Session, Copenhagen, 12 - 16 October 1981

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ANNEX 3

CONTRIBUTION BY MEMBERS ON RECENT RESEARCH RESULTS AND ONGOING AND PLANNED RESEARCH PROGRAMMES RELEVANT TO THE WORLD PLAN OF ACTION ON THE OZONE LAYER

Canada

1. Ozone Monitoring

i) Canadian Ozone Monitoring Network

Canada continues to operate a network of five Dobson spectrophotometers at Resolute Bay, Churchill, Edmonton, Goose Bay and Toronto taking daily total ozone measurements. Weekly ozonesonde flights are undertaken at four of the above five stations (Toronto excluded) to measure the ozone profile.

ii) Brewer Spectrophotometer

Two Mark I Brewer Ozone Spectrophotometers have been actively engaged in field measurement programs as well as in the ongoing ozone and sulphur dioxide monitoring program at Atmospheric Environment Service Headquarters, Toronto, Canada.

One of these two instruments was used in fall 1981 as a travelling standard to intercompare the Dobson instruments at Arosa, Belsk, Bracknell and Brussels.

The new Mark II Brewer Ozone Spectrophotometer is in operation at Toronto. It is also utilized to measure sulphur dioxide amounts for correction of local Dobson values.

Three new Brewer spectrophotometers have been ordered for installation in the Canadian ozone monitoring network. A method for the evaluation of zenith observations has been developed and an Umkehr method is planned. A modification to the Brewer spectrophotometer to permit conversion to UV-B measurement has also been made.

iii) World Ozone Data Centre

Canada continues to operate the World Ozone Data Centre on behalf of the World Meteorological Organization. Data are published monthly in "Ozone Data for the World", along with an annual catalogue of ozone data available at the Centre. Magnetic tapes of total ozone, Umkehr and balloon ozonesonde data are sold to scientists and research institutes at minimal cost.

iv) SBUV/TOMS

Active participation in the SBUV/TOMS net team has continued and a comparison with Canadian Dobson Spectrophotometer data is underway.

2. Recent Research Results and Planned Research Programmes Relevant to the World Plan of Action on the Ozone Layer

i) Stratoprobe Balloon Flights

The analysis of further Stratoprobe balloon flights including one from October, 1980, supports the previous conclusion of low hydroxyl densities in the middle stratosphere. A simulation of this flight with the new NASA - CODATA 1981 reaction rate set reproduces the balloon measurements well.

A scenario with the same chemistry at constant 1979 fluorocarbon usage levels predicts less than 5% ozone depletion in the long term.

ii) Ground Truthing

Ground truthing for the LIMS experiment has continued as well as participation in the HALOE Science Team planning activities.

iii) One-Dimensional Modelling

The York University one-dimensional photochemical model is continually being used to simulate balloon flight results and to conduct scenario calculations. OECD scenarios have been run using the York 1-D model which indicate that ozone depletions of 0.8% should have occurred by 1980.

iv) Two-Dimensional Modelling

The AES 2-D model, incorporating feedback effects between chemistry, radiation and transports, has been run using seven OECD scenarios. Global and annual average ozone reductions for CFC 11 and 12 range from 1.2% for scenario 15 (7% decline), to 27% for scenario 1 (7% growth) in 2020. The estimated steady state value for scenario 8 (constant 1979 emissions) was 5% depletion.

Denmark

Chemical kinetics

3. The gas phase reactivity of Hydroxyl Radicals, OH, toward selected Halocarbons has been studied using the technique of Pulse Radiolysis combined with kinetic absorption spectroscopy. The radiation chemistry of water vapor is well established in terms of the yields of the primary radicals, H and OH, as well as the rate constants for the combination reactions, H + H, H + OH and OH + OH. Rate constants, k(OH + Halocarbon) were calculated from the observed reduction in the life time of OH upon addition of increasing concentrations of the halocarbon. Rate constants derived from simple plots of reciprocal OH-half lives versus halocarbon concentration were in good agreement with the results of more sophisticated computer simulations taking into account all of the competing reactions. In general, the rate constants obtained in the present investigation were significantly higher than those reported in previous investigations applying d fferen techniques and different experimental conditions. In particular, our most surprising result, k(OH + F-12) 1.0×10^7 $M^{-1}s^{-1}$ at at $T = 298^{\circ}$ K is in sharp contrast to an upper limit of about 6×10^5 $M^{-1}s^{-1}$ reported in earlier studies. In view of the implications regarding the tropospheric life time of F-12 we feel obliged to repeat these experiments very carefully in order to eliminate any systematic errors caused by impurities or unexpected competing reactions.

4. Although we have not been able to detect any significant amounts of reactive impurities in the applied F-12 sample our preliminary result on k(OH + F-12) should be taken with reservation until it has been confirmed by the results of continued experimental work.

FEDERAL REPUBLIC OF GERMANY

Field measurements

5. A joint balloon measurement programme of KFA Jülich, MPI for Aeronomy/Lindau (Harz) and MPI for Chemistry/Mainz to investigate the vertical distribution of trace gases has been completed. The results show a reasonable agreement between the three laboratories that analyzed the air samples taken during the balloon flights. The measurements yielded quite a good insight in the vertical distribution of the long lived trace gases H_2, CH_4, N_2O, $CFCl_3$ and CF_2Cl_2 in northern midlatitudes. The CO_2 concentration decrease observed above 10 km altitude can be used to derive the eddy diffusion coefficient distribution of the lower stratosphere.

6. In an additional flight carried out by MPI for Aeronomy/Lindau and AERE Harwell (U.K.), the vertical profiles for F 13, 14, 114, 115, 116 and CF_3Br were obtained.

7. The ozone soundings by balloon ascends of the DWD, Hohenpeissenberg continue to show significantly less stratospheric ozone than corresponding to the long term average, although due to increased sunspot activity some increase might have been expected.

8. The estimated N_2O release rates from soils published in literature, scatter between 0.5 and 5000 µg N_2O-N. $m^{-2}.h^{-1}$, which is due to differences in methods of investigation, soil types, climatic conditions, types of fertilization etc. In a recent investigation of MPI for Chemistry on different types of soil in the environs of Mainz, fluxes of 0.5 - 16 µg N_2O-N m^{-2} h^{-1} were observed on unfertilized natural as well as on agriculturally used soils. The maximum release rate following N-fertilization amounted 43 µg N_2O-N $m^{-2}.h.^{-1}$.

9. The portion of nitrogen released as N_2O into the atmosphere from the mineral fertilizer was 0.01-0,05% for nitrate and 0.0?-0,09% for ammonium fertilizer. If this was true for the globel average, in foreseeable time only a very minor increase in atmospheric N_2O content is to be expected.

Reaction Kinetics

10. The important radical-radical reaction $OH+HO_2 \rightarrow H_2O + O_2$ was investigated using Laser Magnetic Resonance (University Göttingen). HO_2 radicals were generated by three different methods, the results being quite similar. The reaction rate found was $(6.5 \pm 2.5).10^{-11}$ cm^3 $molec^{-1} \cdot s^{-1}$, no pressure dependence was found between 2 and 4 mbar. This rate constant is relatively high, tending to decrease the calculated ozone depletion due to CFC release.

11. A relatively high rate constant was also found by the University of Kiel for the formation of chlorine nitrate according to $ClO + NO_2 + M \rightarrow ClONO_2 + M$. Laser flash photolysis was used for the ClO formation and ClO absorption for analyzing the reaction kinetics. The reaction rate showed an increase of about one order of magnitude from the pressure range of 25-5o mbar to the range of 6oo - 8oo mbar. The reaction sequence:

$$HO_2NO_2 - HO_2 + NO_2$$

$$HO_2 + NO \rightarrow NO_2 + OH$$

can be used as a 'dark' source for OH radicals by adding NO to HO_2 NO_2.

12. This has the advantage of not disturbing the system investigated by photolysis of other compounds and consecutive reactions. At the GH Wuppertal, different reactions of OH radicals including HO_2NO_2 + OH have been investigated.

Biological effects

a) Experiments in growth chambers and in the field

13. At the previous meeting (Bilthoven 1980) results on four plant species (barley, bean, corn, radish) had been reported. They were obtained in a growth chamber with enhanced UV-B intensity (UV-B radiant flux area density) corresponding to ozone reduction rates of more than 20%. In 1981 experiments were conducted with enhanced UV-B radiation corresponding to 10% ozone reduction using plant weighting functions for weighting of UV-B radiation. The weighted daily effective doses were compared to weighted daily effective doses derived from Green's Model. Under these radiation conditions two plant species (bean and radish) were studied very intensively. During growth of seedlings (up to 30 days) samples were analysed each day for estimation of leaf area, weight, photosynthetic function, leaf surface structure, pigment and protein content.

14. Enhanced UV-B reduced the leaf area of primary leaves up to 50% in both plants during development of 20 days. The fresh and dry weight of the leaves radiated with enhanced UV-B were less but significantly reduced up to 16% in comparison to the control plants. The photosynthetic function measured as variable fluorescence, as well as chlorophyll content, was reduced by enhanced UV-B radiation up to 20% in radish leaves, when compared to the same leaf area of control plants. Bean seedlings, however, showed slightly increased photosynthetic activity, which is due to higher chlorophyll concentration per leaf area. When basing the photosynthetic activity on the total leaf area of the plants, the activity is also less in the UV-B irradiated bean seedlings. Stereoscanmicrographs of the UV-B irradiated leaves showed clear damages of the leaf surface (stomata, hairs, epidermal layer). The soluble protein content was increased in both plants with highest increase of up to 60% in secondary bean leaves. The flavonoid content increased 3-fold, especially in radish leaves during leaf development under enhanced UV-B treatment. These and previous results show that the reduction of plant growth, the inhibition of photosynthesis, the changes of leaf surface structure and the composition of plants are a function of the incident UV-B radiation time (= UV-B fluence).

15. The use of the suitable weighting function still remains a problem. Our results were based on a generalized plant response weighting function

according to Caldwell,which gave lower simulated ozone reduction rates than using DNA-weighting functions according to Setlow.Both weighting functions are of lower value for the estimation of UV-B effectivity on photosynthesis or other photo- or biochemical functions in the plant. We therefore started experiments together with Prof. Caldwell (Utah State University) in order to develop polychromatic action spectra for inhibition of photosynthesis in the UV-B-wave band. The following cut-off-filters were used: Schott WG 280 nm, 295 nm, 305 nm, 320 nm, 335 nm 345 nm and 360 nm. It could be shown, that the reduction of photosynthetic activity and of plastoquinone content are both wavelength dependent when using the same UV-B-fluence rate. The dependance on the UV-B fluence has to be shown in further experiments.

16. Further results show, that also under growth chamber conditions using the same cut off filter set a polychromatic action spectra on photosynthetic activity, on plastoquinone content or on hypocotyl length of the seedlings in the UV-B-wave band can be developed.

17. Non-damaging but highly sensitive and specific UV-B effects on cell growth and flavonoid biosynthesis were found in seedlings and cell cultures of parsley and dill. Action spectra for these non damaging UV-B effects were developed with parsley and dill seedlings.

18. Field experiments were continued with crop plants to study the correlations between the UV-B sensitivity and the formation of protective agents. The function of flavonoid pigments as protective agents was demonstrated in parsley seedlings.

b) Experiments with microorganisms

19. The actionspectroscopy in the UV- wave band on the survival and mutation rates during irradiation of yeast cells were continued. Experiments were conducted with high and low fluence rates at several wavelength to show the depencance of survival resp. photoreactivation and mutation induction phemomena on wavelength and fluence rate of the wavelength.

c) future investigations

20. Further experiments in growth chambers and in the field are planned in order to study the correlations between several stress situations arizing in agriculture (nutrients, and water stress, herbicide-stress) and the UV-B stress. Another point of interest is the selection of genetically resistent cultivars of several crop plants.

Some results of ongoing projects in the Federal Republic of Germany

1.) Sources and sinks of relevant compounds

21. Estimates on the production of chlorinated methanes and ethanes in the Federal Republic of Germany (1979) are given in table 1

Table 1
Production data

Compound		Production (Fed.Rep. of Germany, 1979) tons
Methyl chloride	(CH_3Cl)	50 000
Methylene chloride	(CH_2Cl_2)	55 000
Chloroform	($CHCl_3$)	41 000
Carbon tetrachloride	(CCl_4)	207 000
Dichloroethanes	($C_2H_4Cl_2$)	1 300 000
Trichloroethanes	($C_2H_3Cl_3$)	100 000
1,1,1-Trichloroethane	(CH_3CCl_3)	32 000
Trichloroethylene	(C_2HCl_3)	47 000
Perchloroethylene	(C_2Cl_4)	126 000

Total emission data are varying from compound to compound and usually are not available. The emissions of CCl_4 are estimated to amount 5 700 t/a, these for CH_3CCl_3 ca 28 000 t/a in 1979.

22. There is still a considerable uncertainty about the N_2O-release from fertilization; the estimated flux rates reported scatter between 0.5 and 5 000 µg N_2O-N $m^{-2} h^{-1}$. This is due to differences in methods of investigation, soil types, climatic conditions, types of fertilization etc.

23. A recent investigation (MPI for Chemistry, Mainz) on different types of soil in the area surrounding Mainz resulted fluxes of 0.5 - 16 µg N_2O-N $m^{-2} . h^{-1}$ on unfertilized natural as well as on agriculturally used soils. The maximum release following N-fertilization amounted 43 µg N_2O-N $m^{-2} . h^{-1}$

24. The portion of nitrogene released as N_2O into the atmosphere from the mineral fertilizer was 0,01 - 0,05 % for nitrate and 0,03 - 0,09 % for ammonium fertilizer. If this was true for the global average, the N_2O emissions due to fertilization would amount only one to a few percent of the natural injection, and an effect on the ozone layer would be unlikely to occur, independend of results of model calculations of NO_x-effects.

25. The decomposition of $CFCl_3$ on surface of iron oxide was further investigated. The main decomposition products were CO_2, phosgene and $FeCl_3$. The reaction was quite rapid at temperatures above 200°C, but decreased steeply in the temperature range of 100 - 200° C.
Further experiments are being carried out at more realistic surface and environmental conditions.

2.) Field measurements

26. A joint balloon measurement/programme of KFA Jülich, MPI for Aeronomy/ Lindau (Harz) and MPI for Chemistry/Mainz to investigate the vertical distribution of trace gases has been completed.

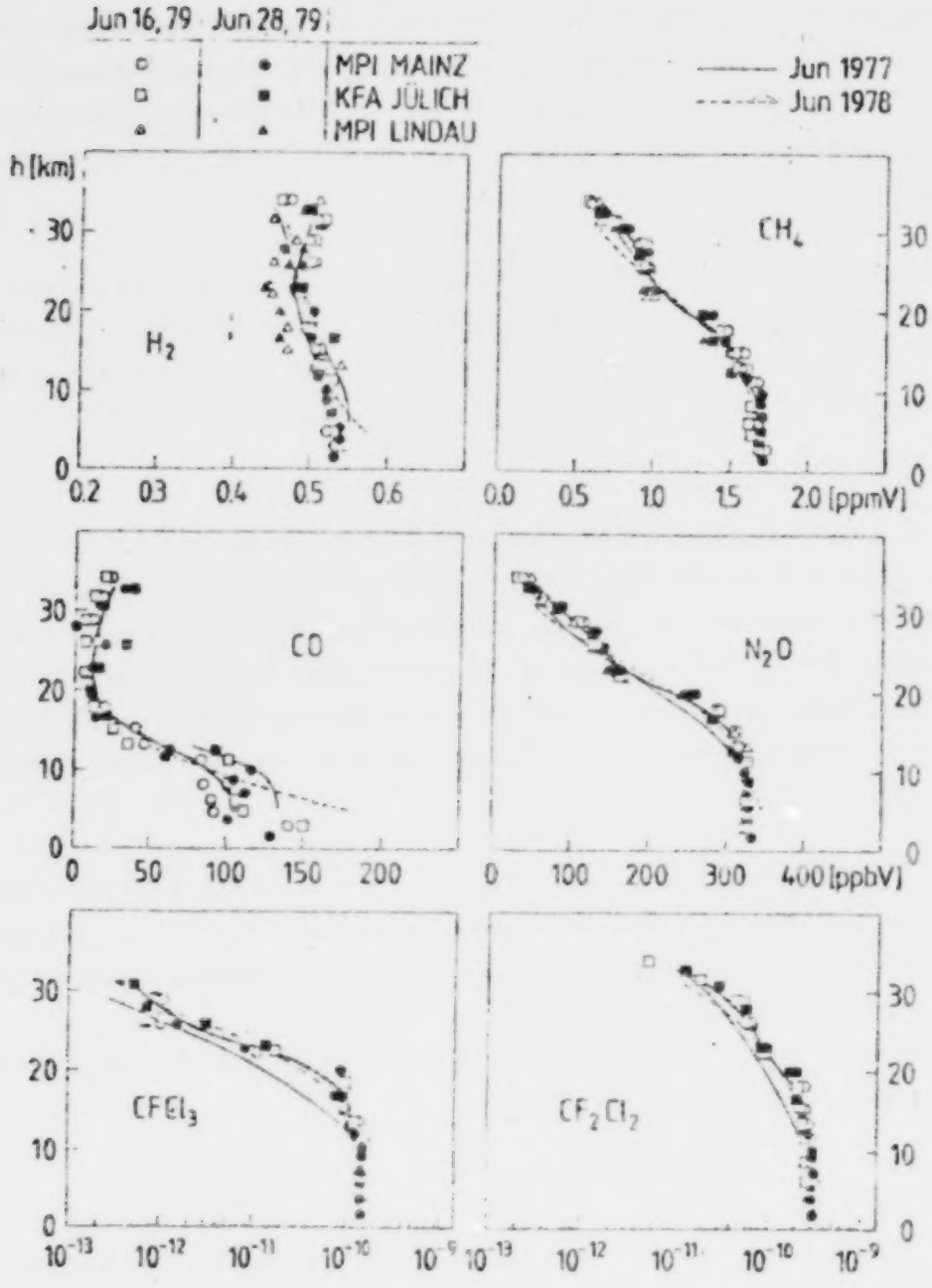

Fig. 1 Vertical profiles of H_2, CH_4, CO, N_2O, $CFCl_3$ and CF_2Cl_2 from 2 balloon flights in June 1979. The mean profiles for June 1977 and June 1978 are given additionally.

27. There was a good agreement between the three laboratories analysing the air samples taken during the balloon flights (fig. 1). The vertical profiles of the long lived constituents obtained at different flights were quite reproducible. The increase of CF_2CL_2 mixing rations observed in the stratosphere from 1977 to 1979 (fig. 2) is much greater than expected due to CFC emissions. To some extend this increase must be caused by different meteorological stratospheric conditions and the deviation can be used to investigate the nature of transport processes other than vertical diffusion.

28. An additional balloon flight has been carried out by MPI for Aeronomy Lindau and AERE Harwell on Sept. 25, 1980 in France (44° N). Besides the vertical profiles of CH_3Cl, F 11 and F 12, this flight for the first time yielded profiles of F 13, 14, 114, 115, 116 and CF_3Br.

29. CH_3Cl is of natural origin, F 14 (CF_4) and F 116 (C_2F_6) are emitted by the aluminium industry, CF_3Br is used as a fire extinguisher, F 113 as a solvent 114 and 115 are refrigerants.

30. The University of Munich participates in evaluation of data from the LIMS-experiment on Nimbus 7. Stratospheric vertical profiles of water vapour, NO_2 and HNO_3 have been derived.

31. Measurements of OH radical concentration have been carried out by absorption measurements using a dye laser at a path length of 10 km. On sunny days from April through September 1979 between 11.00 and 16.00 hours, average OH-concentrations of $(1.7 \pm 0.3) \cdot 10^6$ molecules cm^3 have been obtained at Jülich (25 km east to Aachen); similar values were measured at Deuselbach (Hunsrück) in an rural environment. These number densities are lower than previously estimated.

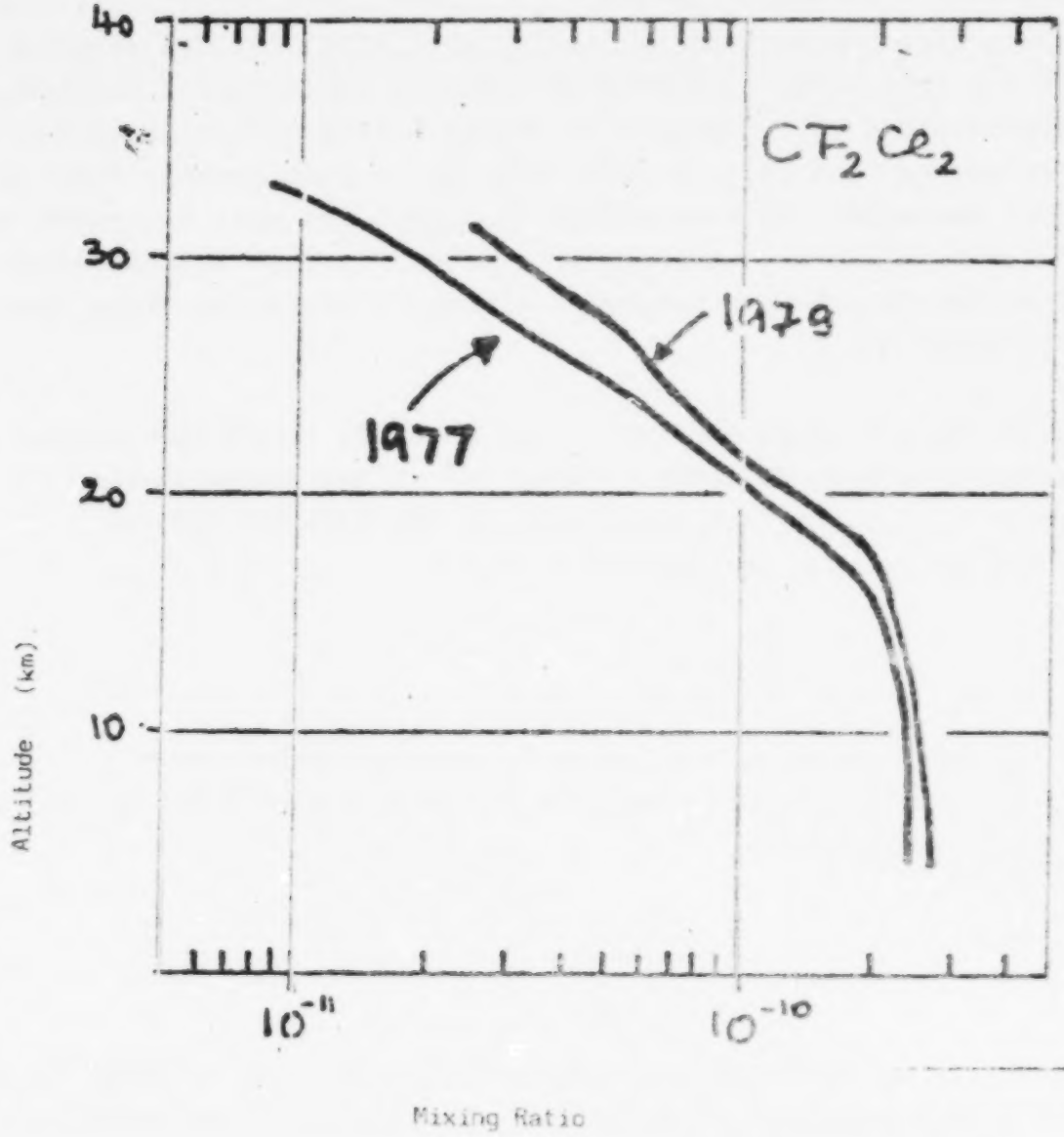

Fig. 2 Mean vertical profiles of CF_2Cl_2 for 1977 and 1979

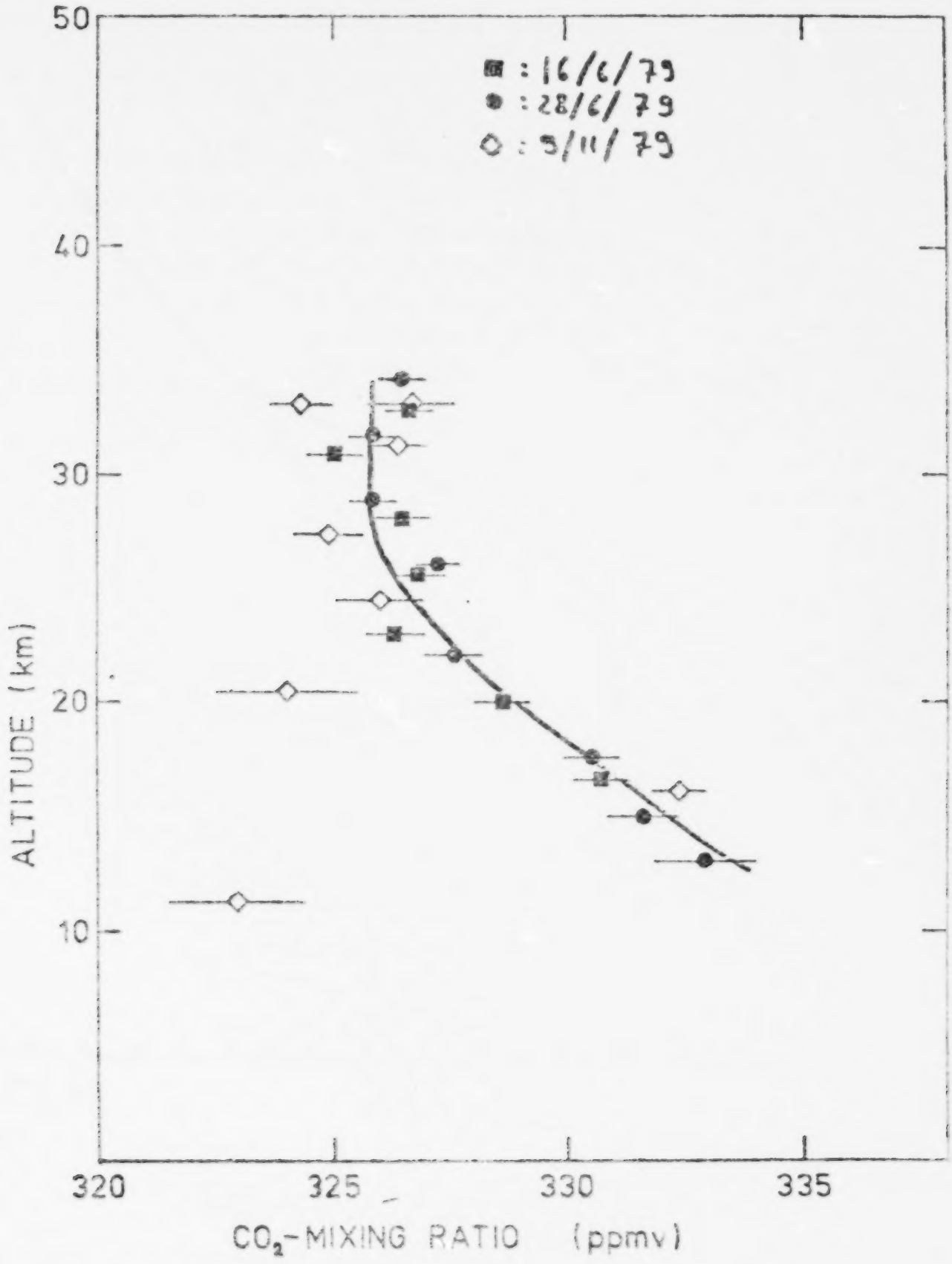

Fig. 3 Vertical profile of CO_2

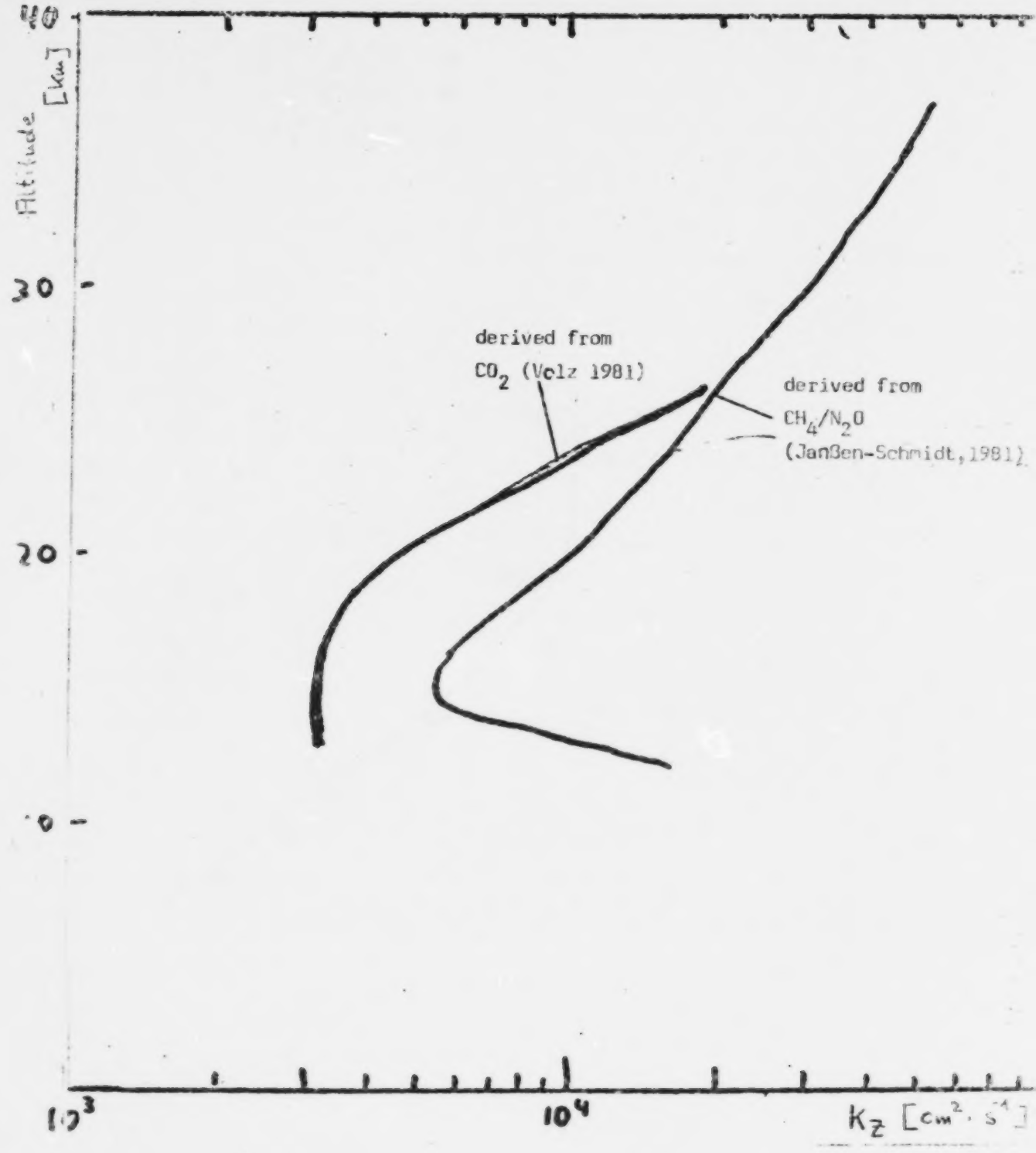

Fig. 4 Eddy diffusion coeffizient K_z derived from CO_2 and CH_4/N_2O

32. Recent measurements indicate, that acetonitrile (CH_3CN) is of ubiquitous occurence. It is not only found in the air of populated and remote areas, but also forms an important constituent of clusterions observed in the stratosphere.

33. The ozone soundings by balloon ascents of DWD, Hohenpeißenberg, continue to show significantly less ozone in the stratosphere than corresponding to the long term average. This ist remarkable, as due to increased sunspot activity, an increase in stratospheric ozone during the latter period might be expected

3.) Reaction Kinetics

34. There is some discrepancy about the formation rate of chlorine nitrate. Kinetical investigations using flow systems and photolytical techniques yielded reaction rates for the formation raeaction (1)

$$ClO + NO_2 + M \longrightarrow ClO\,NO_2 + M \quad (1)$$

about a factor of 2 - 3 higher than those from IR-experiments.

35. The results of a recent investigation by Schindler et al. (University of Kiel) using laser flash photolysis of Cl_2O for ClO formation and ClO absorption for analyzing the kinetics of (1) are given in fig. 5xtogether with results of other authors.

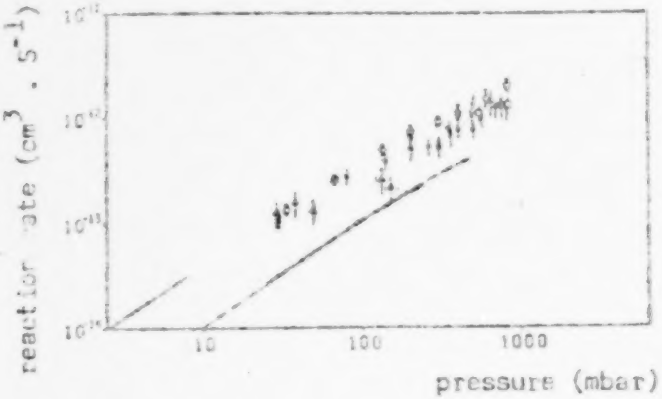

Fig. 5 Pressure dependence of K_1

Legenden: ϕ ▲ ▽ diese Arbeit; ⋮ Cox et al. – – Zahniser et al.
Leu et al. , Birks et al. ; –·–· Knauth ——— Schöule
et al. ····· berechneter Verlauf

36. The low formation rates obtained by IR-investigation of chlorine nitrate destruction or exchange processes deviate from the results. This is possibly due to the existence of other ClO consuming reaction **channels** within these reactions.

37. The photolytical destruction of chlorine nitrate was found to lead primarily to the formation of NO_3 according to (2)

$$ClO\,NO_2 + h\nu \longrightarrow Cl + NO_3 \qquad (2)$$

38. There were some indication for the existance of the complex $ClO \cdot O_2$, which would be of great importance for stratospheric chemistry. This effect needs further investigation however.

The reaction

$$OH + HO_2 \longrightarrow H_2O + O_2 \qquad (3)$$

plays a central role, as this is the main mechnism for destruction of odd hydrogene in the middle and upper atmosphere. Therefore, the value of the reaction rate of (3) is of high influence on the ozone depletion calculeted by models. The measurement of this reaction rate is quite difficult however, different values have been reported and thus there is a considerable uncertainty.

39. Reaction (3) has been studied using the method of magnetic resonance (LMR (Temps and Wagner, University of Göttingen). OH radicals were produced by the reaction

$$F + H_2O \longrightarrow OH + HF$$

while HO_2-radicals were generated by three different reactions:

$$OH + H_2O_2 \longrightarrow HO_2 + H_2O$$
$$F + H_2O_2 \longrightarrow HO_2 + HF$$
$$H + O_2 \xrightarrow{M} HO_2 + M$$

40. Using these three ways of producing HO_2 radicals, the values for the reaction rate constant K_3 ranged between (6.0 and 7.0) . 10^{-11} cm³/molec . s at 296° K, the central value was

$$K_3 = (6.5 \pm 2.5) \cdot 10^{-11} \text{ cm}^3/\text{molec} \cdot \text{s}$$

There was no pressure dependence of K_3 within the pressure of 2 to 14 mbar.

The reaction rate of

$$OH + H_2O_2 \longrightarrow H_2O + HO_2 \qquad (4)$$

was found to be

$$K_4\ (296^0K) = (1,7 \pm 0,3) \cdot 10^{-12} \text{ cm}^3/\text{molec} \cdot \text{s}.$$

Another important reaction rate constant K_5

$$HO_2\ NO_2 + OH \longrightarrow H_2O + NO_2 + O_2$$

was studied by application of fourier transform infrared spectoscopy (FT IR) (Fink and Becker, GH Wuppertal).

41. The OH radicals were generated by adding NO to $HO_2\ NO_2$ in a 420 l reaction chamber via

$$HO_2\ NO_2 \xrightarrow{M} HO_2 + NO_2$$

$$HO_2 + NO \quad . \qquad NO_2 + OH \quad .$$

Such a "clean" source for OH radical has the advantage not to disturb the systems by photolysis of other compounds and consecutive reactions.

The value found for K_4 was

$$K_4 = 4 \cdot 10^{-12} \text{ cm}^3/\text{molec} \cdot \text{s}$$

at room temperature and a pressure of 1 torr.

4. Modelling

42. A one-dimensional modelling system comprising a steady state, a long term and a short term version in a modular construction was developped by GH Essen. The steady state version is suitable to model an atmosphere with all constituents being in equilibrium, the long term version is used for modelling processes with constituents not in equilibrium while the short term version allows modelling of diurnal variations and helps to interpret the results of field measurements.

43. Using the long term version, sensitivity studies were carried out for important trace constituents with respect to uncertainties within the chemical reaction rates. Two examples for the resulting vertical profiles and scattering ranges are given in fig 6. and 7.

44. Special emphasis on 2 D-modelling of diurnal variations including reactive short lived species was given in joint activities of University Oxford and MPI for Aeronomy (Lindau). Although comparisitions with field measurements are problematic, the model seems to simulate the diurnal cycle of minor constituents quite well.

45. It was shown, that for certain reactions large differences between day averages and true dinrual rates can occur

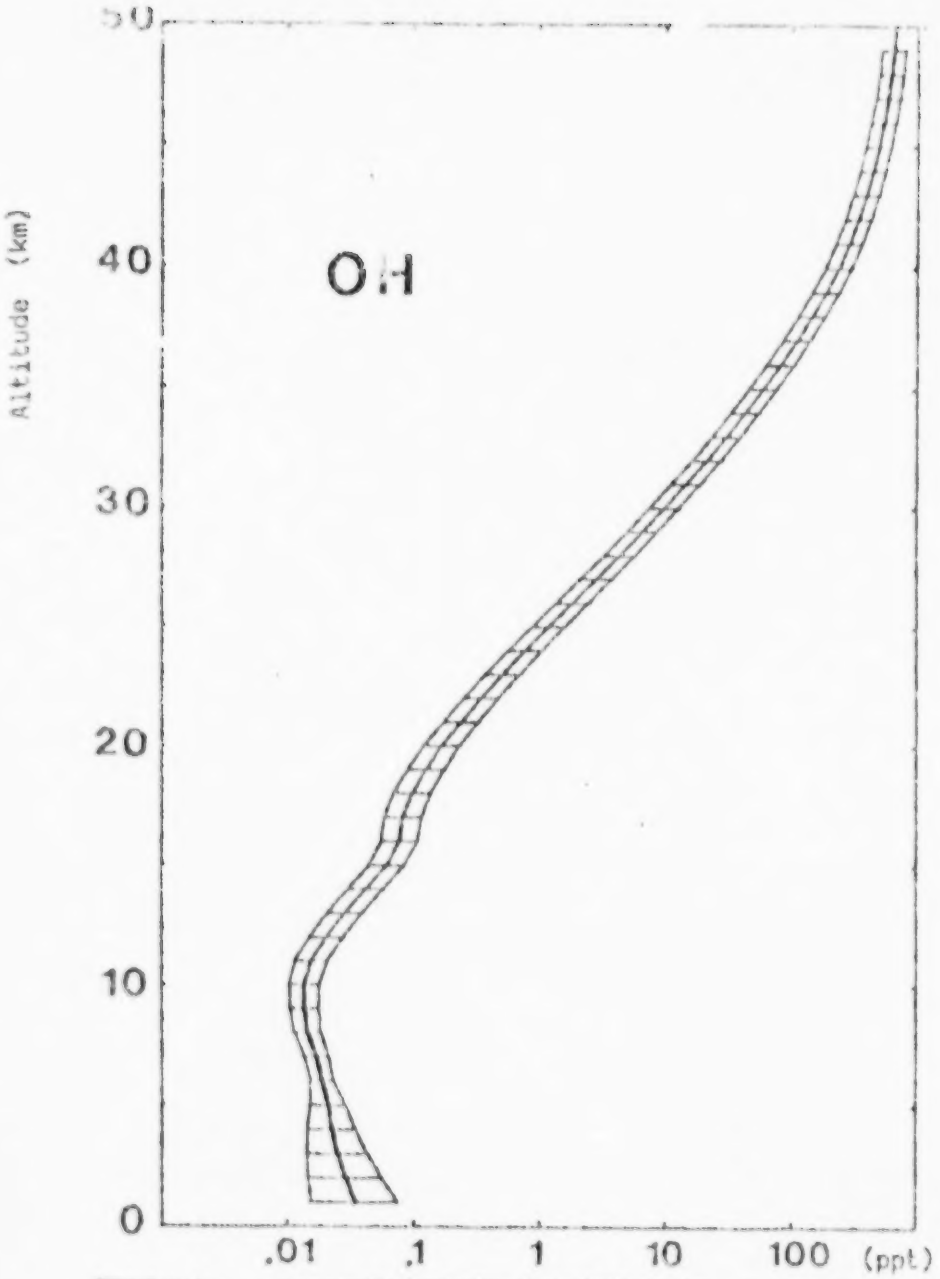

Fig. 6 Calculated vertical distribution of OH

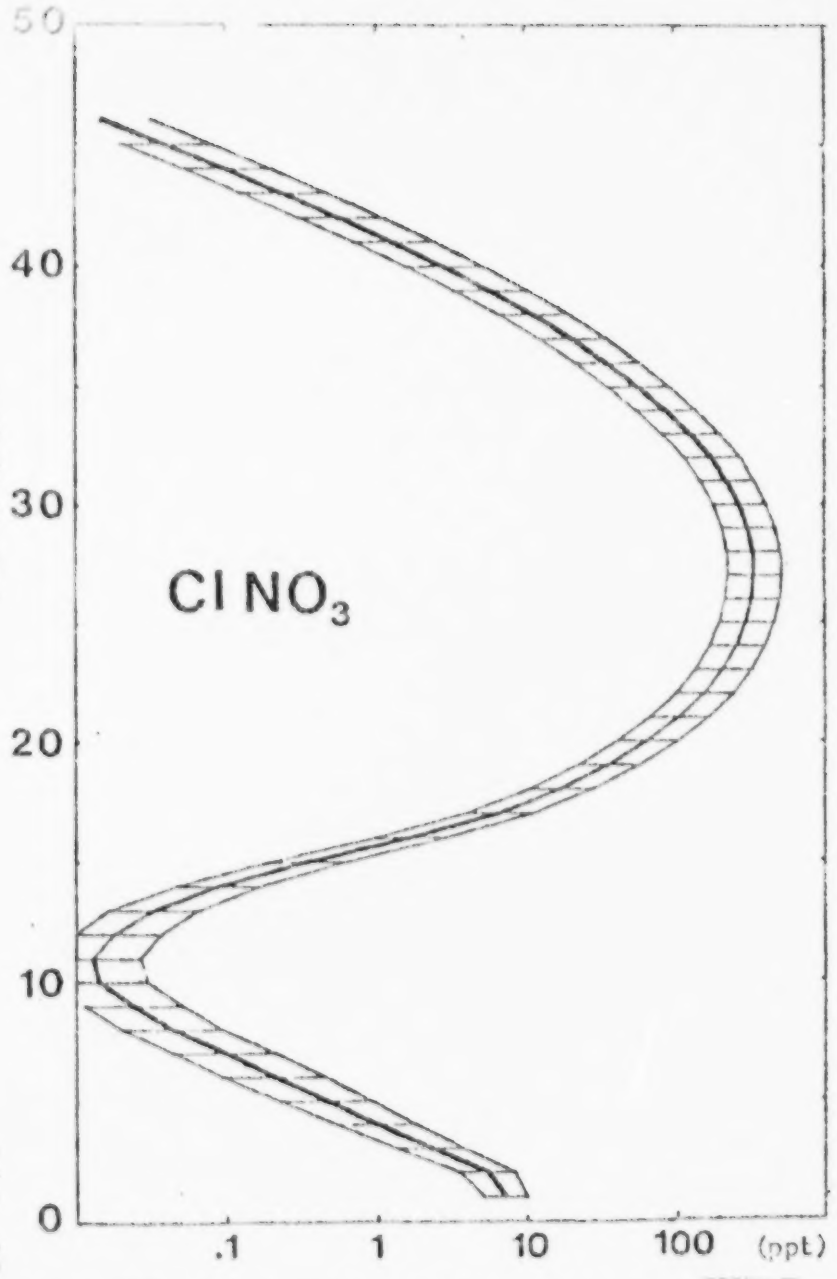

Fig. 7 Calculated vertical distribution of $ClNO_3$

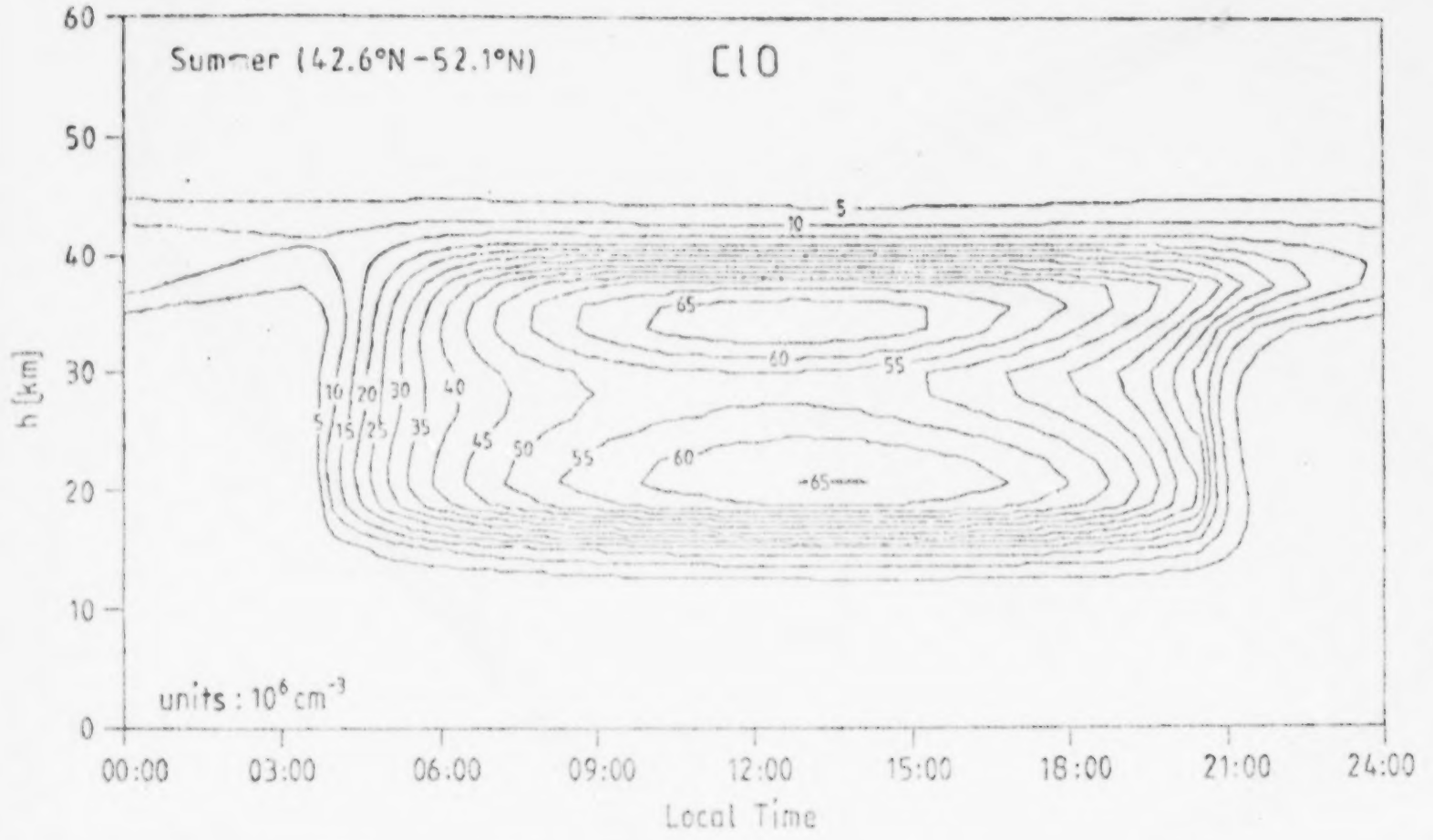

Figure 8: Height-time section of ClO number density ($10^6 cm^{-3}$) for summer, ~ 47°N.

France

46. A continuing program of research is maintained including atmospheric measurements, chemical kinetic studies and numerical modelling. A major effort as been devoted to operating equipment developed in previous years. In particular an international intercomparison campaign of ozone measurement techniques took place in France in June 1981. Complementary research programs are oriented towards the acquisition of better spectroscopic data for the purpose of atmospheric measurements. Development of new balloon techniques for long duration stratospheric flights should in the near future provide novel means of investigation.

I/ OZONE MEASUREMENTS

a) Continuous measurements

47. Dobson stations : Continuous ozone measurements are being carried out at the Biscarrosse SMS station. Observations include daily measurements of total ozone using Dobson spectrophotometers n°49 and 11, weekly launchings of Brewer- Mast ozone sondes and Umkehr measurements during summer time in clear sky conditions. Dobson n° 85 operating at the station located at Magny was temporarily transferred in May 1981 to the Observatoire de Haute-Provence (OHP) in order to participate in the intercomparison campaign of ozone measurement techniques.

b) Non-continuous measurements

1) Satellite measurements

48. A new method for extracting the total ozone content is under development at the Etablissement d'Etudes et de Recnerches Météorologiques (EERM) using data from the TOVS multi spectral telemetry. (See last year's report for further details). First results of ozone mapping show a systematic slant of 100 Dobson Units from the corresponding ozone field obtained from Dobson stations.

49. When the gap is corrected, relative deviation between the two fields is less than 10 per cent

50. From the data of the satellite OSO 8 the Laboratoire de Physique Stellaire et Planétaire (LPSP) has carried out retrieval of ozone profiles between 50 and 70 km. Results at 60 km show a longitudinal variability of the order of 25 per cent at the equator and latitudinal variations during summer.

2) Intercomparison campaign of ozone measurement techniques.

51. This international campaign, sponsored by DGRST (Délégation Générale à la Recherche Scientifique et Technique), was organized with a view to comparing different methods of ozone measurements. It was held during the month of June 1981, essentially at the OHP for ground based measurements and at Gap for balloon flights.

Ground based measurements include :

- Daily total ozone measurements performed using Dobson n° 85. (Numerous Umkehr data have also been obtained).

- Daily vertical profiles of O_3 below 27 km using differential absorption of a backscattered laser signal from a tunable laser (CNRS/SA)

- Vertical profiles and total ozone using SISAM infrared spectrometer (Reims University).

- High resolution UV spectrometer recording spectra in the wavelength range used by the Dobson instrument (Reims University).

- Micro-wave spectrometry located at Bordeaux Observatory for the determination of the vertical ozone profile between 30 and 70 km (Bordeaux University).

Balloon flights :

52. Two successful balloon flights were performed by the Centre National d'Etudes Spatiales. In each flight the balloon platform was loaded with five ozone-sondes :

- A chemiluminescent sonde (CNRC/SA).
- A Brewer Mast Ozone sonde (EERM)
- A U.V. optical sonde (D. ROBBINS, JSC NASA, USA)
- An optical sonde using UV absorption (P. SIMON, IASB, Belgium)
- An optical sonde using UV absorption (A. KRUEGER, GSFC, NASA, USA).

53. During these flights 10 ECC sondes were also launched from the OHP (L. TROAST, Wallops Islands NASA) and from Gap as well as Brewer-Mast sondes from Biscarrosse (EERM).

54. These measurements having been carried out simultaneously both in space and time, this campaign should provide a valuable test for the various techniques used in ozone determination.

Preliminary results should be available before the end of 1981.

II/ MEASUREMENTS OF OTHER MINOR CONSTITUENTS

a) Results from Stratoz II experiment

55. Stratoz II experiment was described in last year's report. Total column measurements of NO_2 above 11 km were made using I.R. grid spectrophotometer (Office National d'Etudes Aérospatiales-ONERA). It has been found that, at sunset, during the month of May total column increases from $1.7\ 10^{15}$ mol. cm^{-2} at 50°S to $4.3\ 10^{15}$ mol.cm^{-2} at 47°N. Such a latitudinal gradient was not observed at sunrise.

56. Column measurements were also performed for HCl, HF and HNO_3. The results show a deep minimum at the equator and a maximum in high latitude regions. Results of air sampling experiments via gas chromatography are also available for $CFCl_3$, CCl_4 and CH_3CCl_3 (Laboratoire de Chimie Analytique Physique, Ecole Polytechnique).

b) Measurements of NO_3

57. A simultaneous night-time observation of NO_3 and O_3 has been made by Université Paris VI (Station Scientifique du Val Joyeux) and the Observatoire de Genève - Switzerland. For the first time the NO_3 vertical distribution was obtained and was found to reach a peak of $3.4\ 10^7$ molecules cm^{-3} at 35 km. A theoretical interpretation of this observation was given using the EERM time dependent 1D model.

III/ CHEMICAL KINETICS

58. New measurements (Centre de Recherche sur la Chimie de la Combustion et des Hautes Températures - CRCCHT) of the reaction OH+HBr gives a rate constant of $92 \pm 0.7\ 10^{-12}$ cm^3 $mol.^{-1}$ s^{-1} at 298°K. This value is in good agreement with the previous determination of Ravishankara et al. The rate of the reaction OH + HNO_3 is also under study. The first results tend to confirm the fast rate determined by Wine et al. as well as a negative activation energy for this reaction.

IV/ EVALUATION OF OZONE TRENDS

59. Optimization of the Dobson network :

An analysis to localize the best site for settling new total ozone stations was made by EERM. The areas proposed tend to confirm previous recommendations given on a more empirical basis by a panel held in Boulder last summer.

60. Frequency analysis of vertical ozone profiles :

The study of vertical ozone profiles over Berlin station shows that after 1970 the ozone layer between 150 mb and 300 mb increases at the expense of the layer above 100 mb. This work will be extended to other ozone stations.

V/ MODELLING

61. The EERM 1D model has been updated with the recent NASA/CODATA 1981 set of rate constants. The major revision since the NASA 1049 publication concerns the rate coefficients for the OH + HNO_3, OH + HO_2NO_2 and OH + HO_2 reactions. As a consequence, the previous estimate of the steady-state ozone depletion of 16.5 per cent calculated for continuing CFC emissions (F11 and F12 alone) at the 1976 rates has been reduced to 7 per cent.

62. A 2D time-dependent transport kinetic model which will calculate the chemical composition of the atmosphere from ground level up to 50 km. is currently under development by EERM. It's chemical scheme is as complete as the one used in the 1D model and preliminary calculations have already shown the stability of the chosen numerical methods.

French plans for a contribution to the ozone layer survey

- ozone profiles:

63. Vertical ozone profiles will be measured using the differential absorption LIDAR Technique in the observatoire de Haute-Provence by the Service d'Aéronomie - Centre National de la Recherche Scientifique. Correlations between profiles and total ozone (TOMS data set - from Nimbus 7), provided by Dr. KRUEGER (NASA/Goddard Space Flight Center), will be examined.

- total ozone:

64. Total ozone willbe retrieved by the Etablissement d'Etudes et de Recherches Météorologiques from satellite (TIROS N/NOAA) radiometer measurements received in Centre de Météorologie Spatiale - Lannion - France. Similar retrieval could be achieved from other satellites (Meteosat Data Sets) if the same channels were included in the measurement device.

65. The Laboratoire de Météorologie Dynamique is testing a new method of inverting the radiative transfer equation. It might eventually be used to retrieve total ozone from TIROS N/NOAA satellites data sets.

Physical Research Laboratory, Ahmedabad, and the National Physical Laboratory, New Delhi.

UV-B Monitoring

70. To measure directly the erythemal effective radiations in the UV-B region, an UV-B photometer was fabricated and installed at the NPL in November 1979 and has been in operation since. The centre wavelengths are at 280 ± 10 nm, 290 ± 10 nm and 310 ± 10 nm. The photometer is steerable and follows the Sun. A second photometer (non-steerable) has been built and is generally loaned to other workers. A recent use of this photometer was by Saurashtra University for study of desert ecology. Work is also in progress in developing and calibrating UV-B sources.

Total Solar Eclipse of February 1980

71. Taking advantage of the occurrence of the total solar eclipse of Feb. 1980 in India, a major ozone campaign was undertaken. The purpose was to monitor ozone over a wide variety of heights from surface to the mesosphere and for this purpose in addition to the existing network, a Dobson Spectrophotometer was operated at Ondey within the totality belt, four rocket flights were launched from Thumba with ozonesondes and special balloon measurements were undertaken. At stratospheric heights no change in ozone was expected and none was observed. Near the surface a decrease in ozone was seen and in the mesosphere a small increase. The chemistry of the mesospheric increase is now under investigation.

Terrestrial Plants

72. In this area work is relatively recent. The different activities include effect of radiation on agricultural systems in the Indian Agricultural Research Institute, New Delhi; plant physiology related to pollution by the Department of Advanced Study in Botany, Madras University; desert ecology

by Gauranhiem University. A programme of special interest concerns the examination of possible inter-relationship between desert ecology and UV-B radiation. There is a plan to study C-4 plants like grass and members of cyperaceae which cover large majority of land area under tropics.

Assessment

73. Considerable work has been done in the MPI on the assessment of related impact of anthropogenic and natural events in producing changes in ozone. The multiplicity of solar and non-solar sources that can operate simultaneously or nearly simultaneously to lead to both short-term and long-term changes in the ozone has been qualitatively examined. In this study, the last decades 1950-80 was considered. Over this timeframe events that could have produced sizable changes in atmospheric minor species of climatic and biological interest were considered. Time profiles of NOx and ClX over this period were computed: in the case of NOx, by considering injections from atmospheric nuclear explosions in 61-63, from solar proton events from 1956 onwards and from galactic cosmic rays. For ClX, injections from volcanic eruptions and from CFMs were combined. ClX time change was calculated for hundred years since 1850, around the Krakatoa explosion period.

74. Since the ozone problem can be understood only if its many reactions (production and loss) with other minor species as well as variation in these species are simultaneously examined, it was considered necessary to prepare reference profiles for India of at least the most important minor species. Such a model has been prepared covering not only the troposphere and the stratosphere but also the mesosphere, covering the entire height range of 0 - 100 Km.

75. Another study was the examination of the role of ions in minor constituent chemistry. Since ions exist right down to the troposphere even

at equatorial latitude, its interaction specially at times of major solar events cannot be ignored. It is also possible that while the proton events are limited to high latitude, the effects may extend beyond this region through global electrical circuits. With this in view, the total ion chemistry of the region from ground to 100 km was modelled at NPL through a comprehensive ion chemical model that includes aerosols.

Indo-US Workshop on Ozone Problem in Delhi, January, 1982

76. An Indo-US Workshop is being organised in India in January 1982 to have a detailed discussion and prepare programmes for the next few years on (i) various types of measurements of ozone over India and its modelling, (ii) measurements of other atmospheric minor species which affect ozone, (iii) climatic effects of ozone variation, (iv) effects of increased UV-B radiation on plants and ecosystems, and (v) enhanced UV-B effects in areas of skin melanoma, aging of skins, pigmentation etc.

Plans for International Symposium on UV-B Effects on Plant Photosynthesis

77. An International Symposium on "UV-B Effects on Plant Photosynthesis" is planned to be held in India late 1982 by the International Association of Photobiology and the Indian Photobiology Society. The planned programme involves molecular and organellar effects of UV-B in plants, UV protection mechanisms in plants and UV-B effects on crop and ecosystem level.

Italy

A report to UNEP on Atmospheric Research Activities
(August 1981)

78. The following summary refers to the continuing programme of activities maintained in Italy in connection with stratospheric research.

Modelling

79. The 1D radiative-photochemical convective model developed at the Physics Dept. of the University of l'Aquila has been implemented with the inclusion of the radiative contribution due to CH_4 and N_2O.

80. The same group at l'Aquila has been involved with 2D-model simulation of aerosols production from Mt. St. Helens volcano.
The 2D model, previously described and modified in order to include sulfur chemistry, has been used to calculate particulate matter production from eruptions containing SO_2, COS and H_2SO_4.
Preliminary results indicate an abrupt decreasing of SO_2 with a production of H_2SO_4 and consequently of aerosols.
These results are in agreement with the experimental data obtained after the eruption.

81. At the University of Rome, Physics Dept, and at the IFA/CNR Roma, Prof. G. Fiocco and collaborators are carrying out research on the cold trap mechanism at the tropopause, on the presence and effects of stratospheric ice clouds, and on stratospheric effects of volcanic eruptions.

Atmospheric measurements

82. At the University of Florence, a program of measurements with stratospheric balloons aiming at the identification and evaluation of vertical profile and diurnal variability of some stratospheric constituents (HCl, HF, ClO, BrO, H_2O, O_3, HNO_3, N_2O) is in progress from 1976. A high resolution spectrometer operating in the submillimeter spectral region, designed and built by IROE-CNR/University of Florence, and a near IR grating spectrometer, designed and built by NPL(U.K.), have been flown together in 1978 and 1979 for simultaneous measurement of the emission of molecular stratospheric constituents. The analysis of the submillimeter data is being implemented with laboratory measurements of the rotational spectra of many relevant molecules. This work is made in collaboration with experts from the Laboratory of Molecular Spectroscopy (CNR) and the University of Bologna.

83. At the University of Urbino, Prof. Bruner obtained some quantitative results on the occurrence of F-21 ($CHFCl_2$) in the troposphere. These results (Annali di Chimica 70, 631, (1980)) should be regarded as the first observation of this compound.
The data from samples collected in tropical and equatorial location (Red Sea - Indian Ocean) show the presence of F-21 in very high concentration from a minimum of 8 to a maximum of 131 pptv with an average of 31 pptv. Data from other locations show the presence of F-21 from zero to $\simeq$ 8 pptv.

84. A possible explanation which seems to be consistent with the data, even though tentative, is that F-21 is formed in desert area.

Ozone monitoring

85. The Dobson spectrophotometers of the national Ozone monitoring network have been transferred to Vigna di Valle (Roma) for cali-

bration and intercomparison. All the procedures have been carried out in collaboration with Canadian experts of the O.M.M.
During the year the instruments will be operating in the following places:

Brindisi	instrument	no.	46
Sestola	"	"	48
Napoli	"	"	66
Cagliari Elmas	"	"	113
Vigna di Valle	"	"	47

Epidemiological Studies

86. An epidemiological study of the malignant melanoma of the skin has been undertaken at the Istituto Superiore di Sanità in Rome. Time trend in mortality has been examined in Italy from 1955 to 1975 and a threefold increase (from 0,25 to 0,85 per 100.000) has been observed, which can be due, among other things, to changes in lifestyle of the population.

87. The incidence of malignant melanoma on the population of the city of Rome is being collected in a pilot study for the years 1970-1979. First hospitalization of patients with a histological diagnosis of melanoma who were residents of Rome have been considered. The data so far available, for the year 1979, have shown an incidence of 1,8 x 100.000 per year.
The most common sites of melanoma were the trunk (42%) for males and limbs (74%) for females.

Japan

MEASUREMENTS OF ATMOSPHERIC TRACE CONSTITUENTS RELATED TO STRATOSPHERIC OZONE DEPLETION

88. CF_2Cl_2, $CFCl_3$, and N_2O of air samples were analysed by a GC method. The mean tropospheric mixing ratios were 0.29 ppbv for CF_2Cl_2, 0.18 ppbv for $CFCl_3$, and 0.32 ppmv for N_2O. CF_2Cl_2 and $CFCl_3$ in the surface air of the North Pacific Ocean were also analysed. The mixing ratio of N_2O in the stratosphere decreased with increasing altitude.

89. The mean mixing ratios of CF_2Cl_2, $CFCl_3$, and HNO_2 were obtained from the sunset solar infrared spectra observed at 8 km altitude. The mean mixing ratios were 0.295 ppbv for CF_2Cl_2 and 0.168 ppbv for $CFCl_3$ assuming the uniform mixing along the optical path. Assuming the uniform mixing between the altitudes of 18 km and 28 km, the mixing ratio of HNO_2 was 9.08 ppbv.

90. Special distribution of ozone around the tropopause gap was observed in order to understand the mass exchange mechanism between the troposphere and the stratosphere.

91. The observation of the ultraviolet direct solar radiation spectra from the ground was continued.

92. The distribution of trace atmospheric constituents were calculated using an 1-dimensional model, and the results were compared with the observations.

The Netherlands

93. In the human health section, the fact that UV-B radiation can induce skin cancer, is still the main issue. The fact itself is well-established.

94. Last year's report mentions, an influence of UV-radiation on the immunologic system. It forms part of the attempts to understand by what mechanisms UV-radiation induces cancer in the skin.

95. The previous report contains the statement that UV-radiation impedes the capability of a mouse to reject an implanted tumor induced by UV-radiation in another mouse. This is an important conception, as it suggests that UV-radiation will also impede the ability of the animal to remove a tumor initiated by UV in the animal itself. This latter step was still speculative last year, the transplantation performed in the experiments being an artificial element.

96. There has been some progress in this problem during the past year. Experiments on mice, performed in the Netherlands, have confirmed that UV-radiation does induce an impaired resistance in a mouse against primary tumors, induced in its own skin by UV-radiation. This removes one element of uncertainty in the application of animal-experimental data to the problem of skin cancer in human populations.

Socio-economic section

97. A short study has just been commissioned to up-date a 1976-report on "The Implication of the Control of Flourocarbons in the Netherlands", that formerly was made available to UNEP under the socio-economic section of the World Plan of Action.

98. The additional study will be performed by the same consultant responsible for the original report. It is, in the first place, concerned with the technical aspects of fluorocarbon use and replacement in the non-aerosol sectors.

Switzerland

Ozone Research in Switzerland

Total ozone and Umkehr measurements (vertical distribution) at Arosa

99. The observational series of total ozone obtained since 1926 at the Light-climatic Observatory at Arosa is the longest practically continuous record in the world. Since 1956 the Umkehr method is in addition used routinely for measuring the vertical ozone distribution. The long series of Umkehr observations is of special interest in connection with the CFC-problem because the derived vertical distribution reaches almost to the stratopause and thus includes the layer where the strongest influence of the ClO_x-impact is expected. Since 1967 the observations at Arosa which are now part of the research program of the Laboratory for Atmospheric Physics of ETH-Zürich are done with two instruments side by side for obtaining a better control of the long term stability of the measurements.

Ozone soundings at Payerne

100. The observational program at Arosa based on the Dobson spectrophotometer has been since 1966, paralleled by regular measurements of the vertical ozone distribution (three times per week) using the Brewer-Mast-electrochemical ozone sonde. The routine which was developed during two years at Thalwil near Zürich has since then carried out in collaboration between the Swiss Meteorological Office and the Laboratory for Atmospheric Physics of ETH at the Aerological Station at Payerne. The now 15 years of parallel measurements with a direct method at Payerne and an indirect one at Arosa allow quantitative studies of the smearing effect connected with the latter.

Combination of observational data with a photochemical model

101. Using the sounding data together with a photochemical model it was possible to compute the ozone flux divergence between 10 and 30 km over mid latitudes as a function of season. Using the available data from the world network the global distribution of the flux divergences could also be obtained, they give a reasonable idea of the meridional fluxes, however, do not allow a quantitative calculation of the fluxes themselves.

Microwave Technique for measuring the vertical ozone distribution

102. Recently a method for obtaining the vertical ozone distribution using measurements in the microwave region (142 GHZ) has been developed at the Institute for Applied Physics of the University of Bern. A comparison with the Umkehr technique is planned for the near future.

103. The instrumentation has also been used from aircraft for obtaining meridional cross sections of the vertical ozone distribution in cooperation with the Max-Planck-Institute for Aeronomy in Lindau/Harz. In collaboration with the same institute the usage of microwave instrumentation from satellite (in the limb scanning mode at 182 GHZ) is proposed.

Tropospheric ozone

104. There are indications, however no definitive proof yet, that ozone concentrations in the troposphere were increasing during the last ten to twenty years. If true, this could alleviate biological consequences of a stratospheric ozone depletion (and at the same time complicate its detection from total ozone measurements);it would, however, not decrease, but rather complicate possible climatic consequences. Considering these new problems research on the interaction between photochemical processes, transport in the boundary layer and dry deposition in connection with local and regional circulations prevailing in hilly or mountaineous terrain has been started at the Laboratory of Atmospheric Physics of ETH-Zürich.

At the Lab. for Physical. Chemistry of ETH-Zürich research on the mechanism of reactions in the photosmog are performed

United Kingdom of Great Britain and Northern Ireland

105. A continuing programme of research is maintained in the UK into the behaviour of the stratospheric ozone layer, the perturbing effects thereon of various gaseous species and consequential changes in ultraviolet radiation at the earth's surface. The programme includes atmospheric measurements, chemical kinetic studies and numerical modell Overall assessment of the ozone depletion problem is also carried out.

Atmospheric Measurements

(i) Ground-based measurements

106. Routine total column ozone measurements have continued from statio operated by the METEOROLOGICAL OFFICE (MO) at Bracknell, Lerwick, St Helena and Mahé, Seychelles. These are published by the World Ozone Data Centre, Downsview, Ontario.

107. The MO Dobson spectrophotometer on loan to the Singapore Meteorological Service was visited and repaired in September 1980 and is now returning regular observations again.

108. A MO technician visited the instrument on St Helena for overhaul and recalibration against the MO standard instrument in December 1980. An additional instrument ordered by the British Antarctic Survey has been received at Bracknell, calibrated and compared with our standard instrument.

109. The instrument from Magny les Hameaux visited Bracknell in June 1981 for checking and adjustment before being taken to the Observatoire de Haute Provence for a comparison of different ozone measuring technic in July.

110. Arrangements have been made for the continuation of ozone measurem from the Seychelles after the withdrawal of British Meteorological Offi staff in August 1981.

111. The BRITISH ANTARCTIC SURVEY (BAS) have continued processing the Dobson spectrophotometer observations made at Grytviken, 54°S, Faraday 65°S and Halley, 76°S, sending the results to the world centre in Toror

112. This coming Antarctic season, BAS [illegible] to launch approximately 70

times when suitable instrumented satellites are flying overhead.

113. HARWELL have continued their long-term measurements of CFC11 and CCl_4. The data set now covers the period January 1975 to June 1981. Measurements of methylchloroform (CH_3CCl_3) have recently been added to the programme. The data indicate that the rate of growth of CFC11 in the atmosphere has slowed down noticeably over the past two years.

114. The present background level at Harwell is estimated to be about 185-190 ppt (parts per 10^{12}). The CCl_4 data can be accounted for on the basis of industrial sources only, there being no evidence for a natural contribution.

115. The long-term measurement of N_2O on a regular basis has also continued at HARWELL.

116. In a cooperative programme between HARWELL and BAS air samples are being obtained on a latitudinal transect between $50^{\circ}N$ and $50^{\circ}S$ using an Antarctic supply vessel. Samples are being analysed for a range of halocarbons and hydrocarbons.

(ii) Aircraft-based measurements

117. The air samples obtained earlier by HARWELL using a commercial Lear-jet have since been analysed. They have established a concentration of 50 ppt for CFC 22 (CHF_2Cl) in the upper troposphere which is unaffected by local sources[1]. This is substantially greater than predicted from release estimates (35 ppt) and suggests these should be re-examined.

118. The measurement programme on long-lived tropospheric precursor molecules carried out by the METEOROLOGICAL OFFICE is continuing using an airborne gas chromatograph on the C130 Hercules aircraft of the Meteorological Research Flight.

(iii) Balloon-borne measurements

119. On 25th September 1980 a balloon probe was launched from Aire sur L'Adour in Southern France (latitude $44^{\circ}N$) to collect large air samples at a number of altitudes [illegible] 10 km. The flight, funded

by the UK Dept. of the Environment, was carried out in cooperation with the Max-Planck-Institute for Aeronomy at Lindau, FGR who provided the air sampling equipment. About 20 litres of air (at STP) was collected at 7 altitudes, 9.9, 14.4, 20.1, 23.3, 25.9, 28.8 and 33.3 km by cryogenic collection using liquid neon. The collected air was subsequently transferred to 1.6 litre stainless steel bottles proven to be contamination-free. The samples were later analysed at HARWELL using gas chromatography and gas chromatography/mass spectrometry (GC/MS)[2].

120. A total of 26 different chemical species were analysed which included vertical concentration profiles for CH_4 and H_2O, and simultaneous measurement of a large variety of chlorine containing molecules. Amongst these were $CFCl_3$ (CFC 11), CF_2Cl_2 (CFC 12), CF_3Cl (CFC 13), CF_4 (CFC 14), $C_2F_3Cl_3$ (CFC 113), $C_2F_4Cl_2$ (CFC 114), C_2F_5Cl (CFC 115), C_2F_6 (CFC 116), CF_3Br (CFC 13B1), CFH_2Cl (CFC 22), CH_3Cl, $CHCl_3$, CCl_4, $C_2H_2Cl_2$ and CH_3CCl_3. The data for some of these compounds are shown in Table 1. The profiles for CFCs 13, 14, 22, 113, 114, 115 and 116 and for CH_3CCl_3 are the first reported and will be of particular value for validation of two-dimensional stratospheric models.

Table 1

Vertical concentration profiles for CFCs, CH_3Cl, CH_3CCl_3 and CCl_4

Balloon flight September 25th 1980 at Lat. 44°N

Altitude	CH_3Cl ppt	CFC11 ppt	CFC12 ppt	CFC13 ppt	CFC113 ppt	CFC114 ppt	CFC115 ppt	CH_3CCl_3 ppt	CC ppt
9.9 km	(477)	(144)	(241)	(5.1)	C	(7.0)	(4.2)	(78.2)	abs
14.4 km	422	178	289	3.9	10.4	8.5	3.1	44.7	abs
20.1 km	183	90.3	189	3.52	5.1	6.0	2.3	17.2	abs
23.3 km	119	14.7	129	2.99	2.73	5.4	1.7	1.04	abs
25.9 km	44	0.28	39.6	2.65	1.0	3.8	1.36		abs
28.8 km	34	0.09	20.8	2.45	0.6	4.4	1.26		abs
33.3 km	54.5	N.D.	8.96	2.26	C	2.7	1.0		abs

C = contaminated

N.D. = not detected

abs - absent

121. Organic compounds which react with hydroxyl radical formed a further group of compounds analysed. Apart from chlorocarbons this included ethane, ethylene, benzene, toluene and vinylidene chloride ($C_2H_2Cl_2$).

122. The stratospheric programme at the NATIONAL PHYSICAL LABORATORY (NPL) is directed towards remote, near-simultaneous measurement of the concentration profiles of inter-related statospheric gases believed to be important to the problem of ozone depletion. A balloon-borne, mid-infrared cooled grating spectrometer is used which can measure the emission spectra of stratospheric species throughout a daily cycle[3]. This instrument employs the conventional limb-scanning technique to derive concentration profiles as a function of altitude. In its present form the spectrometer is directed towards measurements of the NOx family, though several other species are measured such as ozone, water vapour, CFCs 11 and 12 and methane. The experiment is mounted on a stabilized gondola platform developed at NPL. Azimuth stabilization is achieved by sensing the gondola position with respect to the earth's magnetic field and servo controlling the gondola rotation. Stabilization in elevation is achieved by sensing the gondola swing away from vertical and correcting the angle of the limb-scan mirror accordingly. The instrument covers the spectral region 5 to 16 μm and has a resolution approaching 0.1 cm^{-1}; sensitivity is high since the three copper doped germanium detectors are liquid helium cooled and the spectrometer and input window are at liquid nitrogen temperature.

123. In parallel with the major NOx programme has been the development of a simple, light-weight filter radiometer for the measurement of water vapour in the far-infrared. This device can be launched by two standard radiosonde balloons or lends itself to "pick-a-back" operation with larger payloads.

124. During the Spring of 1981 the group co-ordinated and assembled a major collaborative payload onto the NPL gondola. The combined experiment was named NOBLE (Nitrogen Oxides Balance Experiment) and consisted of:

Cooled grating spectrometer	(NPL)
Water vapour radiometer	(NPL)
Pressure modulated radiometer	(OXFORD/JPL)

Ozone sonde	(NASA, HOUSTON)
Two solar flux experiments	(NASA, GODDARD)

The experiments produced much useful data during the 16½ hour flight from Palestine, Texas. The float altitude reached was 38 km.

125. Also during the Spring of 1981 a campaign took place to make near simultaneous intercomparison flights of instruments measuring water vapour. Seven groups participated, five balloons were launched and a U - 2 flight took place. The NPL water vapour radiometer flew on three of the balloon payloads and produced good data.

126. The results of a balloon flight carried out by the Dept of Atmospheric Physics, OXFORD UNIVERSITY, in September 1978 at Palestine Texas have now been published[4]. The Oxford balloon-borne pressure modulation radiometer was used to measure simultaneous altitude profiles of NO and NO_2 from mid-morning till sunset. An improved detector for the NO channel, a better procedure for interpolating between calibration points, and an improved error analysis yielded results of higher quality than from previous flights. During the day the NO_2 column above 24 km increased by 0.42 ± 0.28 to $1.86 \pm 0.24 \times 10^{15}$ molecule cm^{-2}; the NO column above 30 km reached a maximum of $5.2 \pm 1.3 \times 10^{15}$ molecule cm^{-2} soon after noon, falling $1.58 \pm 0.77 \times 10^{15}$ molecule cm^{-2} by an hour before sunset. A detailed comparison of measured NO and NO_2 concentrations with those predicted by the OXFORD two-dimensional diurnal model shows disagreement in their absolute values but close agreement in their day-time changes. The model predicts a fall in NO during the afternoon, as observed.

127. The Remote Sounding Group at the RUTHERFORD and APPLETON Laboratories (RAL) is constructing a balloon-borne microwave radiometer system for upper tropospheric and stratospheric measurements of trace species

(iv) Satellite measurements

128. The Stratospheric and Mesospheric Sounder (SAMS) designed and constructed by the Atmospheric Physics Group, OXFORD UNIVERSITY[5,6] is an infra-red radiometer on the NIMBUS 7 experimental meteorological satellite which was launched on October 24th 1978. It has completed two years of successful operation and preparations are now being made to go into full scale production of archivable data soon to be available

on magnetic tape. Data acquisition is expected to continue throughout the Middle Atmospheric Programme (ie until 1985) and possibly until the launch of an advanced version (ISAMS) on the first Upper Atmospheric Research Satellite in 1987. The data reduction and inversion algorithms will also be subject to continuous improvement as time goes on and so occasional reprocessing of the data obtained since launch, with a consequent revision of the inferred geophysical parameters, is anticipated.

129. Like other equipment on NIMBUS, SAMS is an experimental, not an operational, instrument. It was designed to measure temperature and chemical composition over a wide range of altitudes, using the pressure modulation technique to give high selectivity and sensitivity for the constituents of interest. The molecular species and spectral bands selected for SAMS are summarized in Table 2, which also lists the height ranges over which measurements typically can be made in each case.

TABLE 2. S.A.M.S. RADIOMETRIC CHANNELS

field of view	channel	constituent (gas in modulator)	mean cell pressures mbar	spectral band μm	derived quantities and altitude range
A	A1	CO_2	17, 2.4, 0.69, 0.25	15	kinetic temperature 15–80 km; attitude
	A2				ν_3 vibrational temperature 80–100 km
	A3	CO	14.8, 4.5	4–5	
	A4	NO	45, 20		distribution 15–60 km
B	B1	H_2O	10, 4.5, 0.8, 0.5	2.7	distribution 80–100 km
	B2			25–100	distribution 15–100 km
C	C1	CO_2	36, 11.2, 3.25, 0.87	15	kinetic temperature 15–80 km; attitude
	C2	N_2O	24.4, 7.15	7.7	distribution 15–60 km
	C3	CH_4	47.8, 22.5		

130. The Remote Sounding Group at RAL is assessing the H_2O and NO_2 HNO_3 data from the LIMS infra-red experiment, also carried on NIMBUS 7, to determine global composition distributions and budgets.

2. Laboratory Measurements and Chemical Kinetics

131. Laboratory spectroscopy of H_2O, O_3 and other trace molecules is being carried out by RAL to provide spectral data needed for remote sensing of the stratosphere.

132. At HARWELL the technique of molecular modulation spectroscopy (MMS) has been upgraded by improved data handling facilities and its versatility will shortly be extended by the use of an infra-red diode laser to provide diagnostic capability in the infra-red region to supplement the existing visible and ultra-violet detection systems. The MMS continues to be used to obtain kinetic and mechanistic information.

(i) The reaction $OH + HO_2 = H_2O + O_2$

133. The kinetics of this reaction have been the subject of numerous studies over a number of years. Measurement of the rate coefficien. is experimentally difficult and there remains substantial disagreement between the apparent rate coefficient obtained at high pressure (1 atm) and the value from low pressure flow systems. This reaction plays a key role in the photochemically driven odd-hydrogen chemistry at all altitudes of the atmosphere, since it leads to a net removal of OH, the most important species promoting the oxicative degradation of many trace gases. The use of the upgraded multichannel detection system for the molecular modulation spectrometer in which the fully time-resolved waveform for absorption is recorded, has greatly facilitated the extraction of kinetic information from this kinetically complex reaction[7]. A value of $(9.9 \pm 2.5) \times 10^{-11}$ cm^3 molecule^{-1}s^{-1} at 308°K and 1 atmosphere pressure was obtained in excellent agreement eith recent values near 1.0×10^{-10} cm^3 molecule^{-1}s^{-1} obtained elsewhere from investigations conducted at high pressure using steady-state photolysis, flash-photolysis and pulse-radiolysis. It is however significantly higher than the range 2 to 5×10^{-11} cm^3 molecule^{-1}s^{-1} based on a number of low pressure discharge flow experiments.

(ii) Reactions of BrO

134. The absorption spectrum of BrO was determined[8] from measurement of the in-phase components of modulated absorption in the photolysis of Br_2-O_3-O_2 mixtures. The observed spectrum consisted of 17 bands in a progression from 361 nm to 297.6 nm. Using standard data for the solar flux near the ground the photolysis rate of BrO was calculated to be $J(BrO) = 3.4 \times 10^{-2}s^{-1}$ for a solar zenith angle of 30°.

The kinetics of the reactions

$$BrO + BrO \rightarrow Br_2 + O_2$$

and $BrO + BrO \rightarrow 2Br + O_2$ k_2

were investigated[8] by photolysing Br_2 in the presence of O_3. From measurements using the multichannel detector to monitor BrO the rate coefficient k_1 was determined as $(6.6 \pm 2.0) \times 10^{-13}$ cm^3 $molecule^{-1}s^{-1}$ over the temperature range 278-346°K and by measuring the quantum yield for the Br_2 photo-sensitised decomposition of O_3 at 302°K, the value of k_2 was estimated as 3.5×10^{-12} cm^3 $molecule^{-1}s^{-1}$.

135. The reaction of BrO with HO_2 was studied by simultaneous production of these radicals in the photolysis of O_3-O_2-Br_2-H_2 mixtures. Concentration-time data for BrO and HO_2 monitored in separate experiments at different monitoring wavelengths and under conditions where the photochemical production rates for the two species were nearly equal, were fitted by computer simulation to obtain an estimate of 4.3×10^{-12} cm^3 $molecule^{-1}s^{-1}$ for the reaction $BrO + HO_2 \rightarrow HOBr + O_2$.

136. Bromine is a potentially powerful catalyst for destruction of ozone via chain reactions involving Br and BrO. Although the photolysis rate for BrO determined in this study constitutes a significant reaction of BrO in the stratosphere, its effect on the catalytic role of bromine species in O_3 depletion will probably be small since it does not give rise to loss of active Br. However the reaction of BrO with HO_2 is postulated to yield HOBr which may act as a temporary reservoir species. This would tend to reduce the concentration of active Br.

Numerical Modelling

137. At the METEOROLOGICAL OFFICE, examination of the correlations between water vapour and ozone in a stratosphere-troposphere general circulation model has been carried out, and the effects on the global distribution of OH calculated[9].

138. Detailed calculations of the diurnal, seasonal and semiannual variations of ozone and temperature have been made in the stratosphere with a radiative-photochemical column model at a range of latitudes, and the data compared with satellite observations. A preliminary account of this work is included in the collected extended abstracts of the 1980 Quadrennial Ozone Symposium, held at Boulder.

139. Also at the METEOROLOGICAL OFFICE, there is work on three dimensional models with emphasis on dynamics though the interactions

and transport of minor constituents are also included.

140. The stratosphere-mesosphere model used as the basis for these studies has as its lower boundary condition specified geopotential heights in the tropopause region, in order to parallel the forcing provided by tropospheric planetary waves without the complexity of a tropospheric general circulation model. This model structure also conveniently allows use of the model for idealised experiments and studies of specific observed events. Comparisons of circulation with observations from the Meteorological Office's Stratospheric Sounding Units (SSUs) on board NOAA operational satellites is used both for atmospheric studies and guidance in model development. Some of this work has recently helped in elucidation of the mechanism of the wavenumber two sudden warming of February 1979. It was demonstrated in a set of model experiments that the occurrence of warming depended upon both the non-climatological circulation prior to the warming and the phase speed of the forcing wave in the troposphere. Because acceleration of the circulation and transport are intimately linked, results such as these have also implications for the fuller understanding of the behaviour of trace species.

141. A version of this model is also being used to study the evolution of an ozone-like tracer in the presence of a transient planetary wave disturbance. Diagnostic techniques are being developed to clarify the contributions of wave transience and induced chemical interaction to the net flux of minor constituents. Recent effort has been mainly directed twards simulating the observed circulation well enough to allow realistic description of the propagation and effects of wave disturbances. Test integrations have been able to reproduce the maintenance of the polar night jet quite well using calculated radiative forcing and observed planetary wave characteristics. These should provide a reasonably quantitative basis for further study of budgets of dynamical variables and idealised tracers.

142. An advanced treatment of transport processes is being attempted with the OXFORD UNIVERISTY 2D model. In this treatment the well-known cancellation between the mean and eddy transports is modelled explicitly. The net mean transport is accomplished by the diabatic circulation. Eddy contributions to net transport, which depend on the chemical lifetime of the particular consituents are also calculated from a

description of planetary wave propagation. Preliminary calculations are encouraging producing, for instance, the major features of the ozone distribution.

143. The HARWELL 1-D model has been continuously updated during the past year to reflect the changes in stratospheric chemistry resulting from new laboratory studies and chemical kinetic rate evaluations. Since the previous UNEP evaluation in 1980 new data for the reactions $OH + HNO_4$, $OH + HO_2$ and $ClO + NO_2$, together with numerous minor changes to the $O(^1D)$ rate coefficients, $NO + O_3$ etc have been incorporated. Using the latest evaluations from the combined NASA-CODATA chemical kinetics panels, a total column ozone depletion of 6.7% is currently calculated at steady state for releases of CFC 11 and 12 continued indefinitely at their 1976 rates. This value should be compared with a figure of 10.7% calculated at the time of the 1980 meeting of the CCOL and is about one third of the prediction made in 1979 when estimates of future ozone depletion reached a peak.

144. The fluctuations in predicted ozone column depletion resulting from 1D model calculations carried out at various times since 1976 using on each occasion the best currently available chemical kinetics data are shown in Fig. 1. The results of some calculations by other groups are also included.

145. At the present time, total column ozone depletion is estimated to have reached 0.65%. At 40 km, where the effect of CFC 11 and 12 are expected to be larger relatively, the depletion is estimated to be 2.5% currently and to reach 25% at steady state. If CFC 11 and 12 production rates are held constant at their 1979 levels (which were lower than in 1976) then the total column ozone depletion is not expected to reach 2% until about 2000 AD.

146. At present, validation of the models used to predict ozone depletion can only be carried out by comparison of model and observed values for the present day levels of a number of trace species in the stratosphere. The HARWELL 1-D model has been used[10] to examine the adequacy of currently available atmospheric data for this purpose. It was shown that different model formulations which result in predicted ozone depletions differing by a factor 2 result in changes in the calculated present day levels of trace species which are well within the current

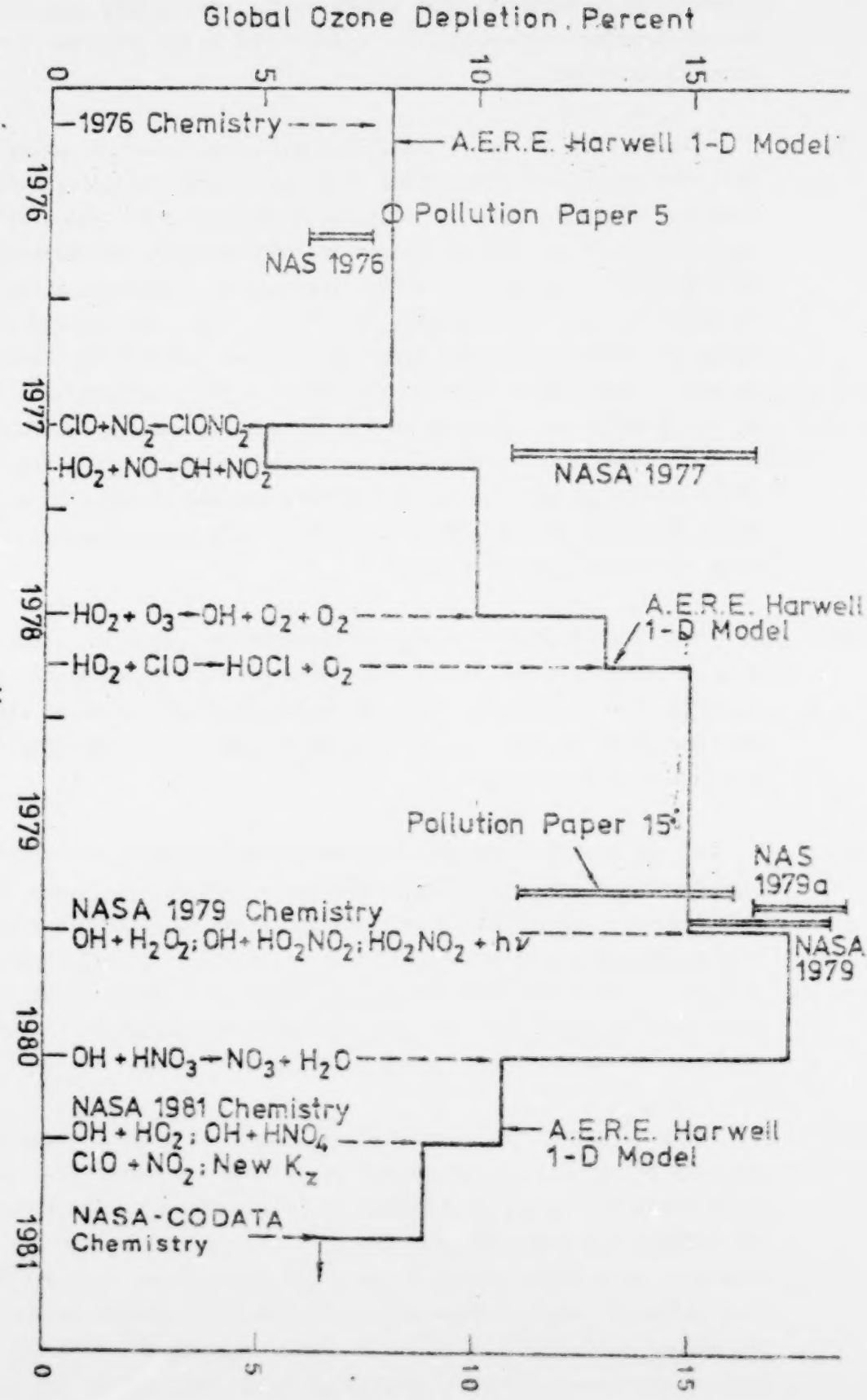

FIGURE 1 The possible steady state global ozone depletion due to the continuted release of CFCs 11 and 12 at the 1976 production rates calculated with the AERE Harwell 1-D model. The figure shows the effects of the major re-evaluations in the chemical kinetic input data and the ozone depletion estimates given in the major reports on the stratospheric ozone layer.

error limits of such measurements. Thus, available atmospheric data do not provide the means of validating atmospheric models with the accuracy required and considerable improvement is needed both in coverage and precision.

147. From an examination of the behaviour of halocarbons and reactive chlorine in a one-dimensional photochemical model of the stratosphere it has proved possible to construct simplified models which faithfully reproduce the predicted behaviour in the more complex models. In this way, it is possible to evaluate the effect of complicated patterns of halocarbon usage on the stratospheric ozone amount from the results of a few experiments with the more complex one-dimensional model, with a large saving in computer time.

148. The HARWELL 2-D model has been used to investigate possible ozone production in the troposphere as a result of emissions of NOx from subsonic aircraft[12]. The effect is found to be more marked in the northern hemisphere than the southern hemisphere and most noticeable in the summer upper troposphere. The increase in total column ozone at 30°N (annual mean) is calculated to be ~ 0.3% on the basis of 1975 aircraft NOx emissions (4.9×10^8 kg NO_2 yr^{-1}) with a local increase of 2% between 8 and 10 km altitude at 30°N in summer. This calculated ozone <u>increase</u> may well have largely offset the present day predicted <u>decrease</u> in total column ozone due to CFCs 11 and 12 in the northern hemisphere but to have only a minor effect on that in the southern hemisphere where the effects of aircraft emissions are smaller.

4. <u>Assessments</u>

149. A review of the effects of man-made pollutants on the stratospheric ozone layer has recently been published[13] which assesses some of the changes which have occurred since the publication of the UK Dept of Environment's Pollution Paper No.15 (chlorofluorocarbons and their effect on stratospheric ozone).

World Health Organization

WHO Activities for Implementation of the World Plan of Action on the Ozone Layer

150. During 1981 a project proposal for monitoring of health effects of ultraviolet radiation was prepared and submitted to UNEP for consideration. Under this proposal the following three main activities are envisaged:

1. Collection and processing of retrospective data on the incidence of melanoma and non-melanoma skin cancer in relation to ultraviolet radiation levels.

2. Coordination of ongoing national studies on special population groups.

3. Special study on skin cancer incidence in relation to geographical distribution of ultraviolet radiation levels.

151. In addition to the collection of national data on ultraviolet measurements provision of unified ultraviolet dosemeters is planned and intercomparison measurements are envisaged, if necessary.

152. Within the next several years it will be necessary to review the WHO/UNEP Environmental Health Criteria Document on Ultraviolet Radiation, which was prepared in 1977, but issued only in 1979, and if necessary to issue an addendum on the new scientific data, measurements and health risk estimates This addendum could be prepared by a small group of experts.

153. A review paper on ultraviolet effects prepared for WHO by the USSR and is presented for the attention of the members of the Coordinating Committee on the Ozone Layer.

World Meteorological Organization

INTRODUCTION

154. It will be recalled that WMO was designated lead agency in several fields of the World Plan of Action on the Ozone Layer and its activities are being carried out within the WMO Global Ozone Research and Monitoring Project established by the WMO Executive Committee in Resolution 8 (EC-XXXIII) in 1976.

PURPOSE OF DOCUMENT

155. This document informs the UNEP Co-ordinating Committee on the Ozone Layer of progress made by WMO of direct concern to the implementation of the World Plan since the fourth session of the Committee (Bilthoven, November 1980) and makes proposals for future activities and support.

DISCUSSION

156. The WMO Executive Committee at its thirty-second session, in considering future activities for the WMO Ozone Project, felt that efforts in future years should be directed towards promoting:

- Studies aimed at clarifying physical processes and phenomena which are relevant to ozone photochemistry and stratospheric dynamics;
- Studies of the radiative effect of ozone and other minor species relevant to ozone photochemistry and stratospheric dynamics;
- The use of multiwave-length "short Umkehr" evaluations to achieve a significant increase of vertical ozone profiles, and
- Studies of the affect of aerosol contamination of the stratosphere on Umkehr evaluation.

Total ozone

157. Efforts have continued to upgrade and standardize the global total ozone observing network upon which most other activities in the World Plan depend to some degree. These efforts, detailed below, have been actively supported by UNEP for which WMO is thankful.

158. In the past year, WMO has arranged for upgrading, reactivating, checking and/or re-locating Dobson spectrophotometers 7,17,35,43,47,64,69 and 100. Instrument No. 7 (located at Singapore) was recalibrated after developing a fault; No. 17 was modernised and calibrated by the Canadian AES and returned to Invercargill (New Zealand); an expert visited No. 35 located at St. Helena for calibration and maintenance; No. 43 was returned to Quetta (Pakistan)

following upgrading by the Canadian AES; No. 47 from Italy was re-calibrated after developing problems; No. 64 was calibrated and upgraded by NOAA and will be returned to Egypt and No. 100 was upgraded and then calibrated relative to No. 43 at Quetta. The UK secondary standard No. 41 was carefuly inter-compared with the world primary standard No. 83 at Boulder, Colorado.

159. The WMO Executive Committee at its thirty-third session (June 1981) designated the NOAA laboratories in Boulder, USA as the World Dobson Spectrophotometer Control Laboratory with the function of maintaining Dobson No. 83 as the world primary standard spectrophotometer and of assisting in the upgrading and comparisons of other Dobson ozonespectrophotometers as necessary.

160. Until recently, comparisons between Dobson instruments brought together at a particular location have been the primary means in trying to ensure standardization of ozone observations and data. However, for various reasons (mainly, lack of financial resources) the system is not working as well as desired. Therefore, WMO, taking advantage of the development of the readily portable Brewer spectrophotometer, has arranged for travelling comparisons. An expert with a well calibrated Brewer instrument visited Europe for purposes of comparing Dobson instruments at Belsk, Arosa, Uccle and Bracknell. It is still too soon to report on the success or not of this exercise but first indications are encouraging.

161. A further method for calibrating the global Dobson network has been implemented. In this instance, the world's active Dobson instruments have been divided into seven regional groupings to which calibrated standard lamps sets, payed for by WMO and kindly supplied by NOAA, have been sent. These lamps are intended to be shipped to each station in turn over the course of a year and then returned to NOAA in Boulder where the N values would be checked and the lamps sent back to the stations for the exercise to be repeated. Theoretically, by providing indications of the current conditions of various instruments and identifying needs for revision and comparison, this mechanism is a more efficient and much less expensive way to maintain high standards in the global network.

Vertical ozone distribution

162. Arrangements were made for the Indian balloon-borne ozonesonde to be compared with the FRG used sondes at Hohenpeissenberg in December 1980. This development means that all the world's operational ozonesondes have now been compared relative to each other, thus completing the programme started in 1978. The differences existing between various types of ozone-sondes must be considered in any analysis of vertical ozone distribution.

163. WMO has recently arranged for an Egyptian expert to visit the Hohenpeissenberg observatory for purposes of instruction on the operation of balloon-borne ozonesonde observations which are due to start on a trial base in Cairo.

164. WMO has informed Members of the development of the short Umkehr method for determining vertical ozone profiles using Dobson spectrophotometers. This method reduces the time required from about 5 hours to 1-3 hours. Extensive use of the method would provide researchers with a great deal of valuable vertical distribution information, particularly in the 30-50km layer.

165. As has been reported to previous CCOL sessions, WMO supported by FAA NOAA and NASA is engaged in a large study of assessing performance characteristics of various rocket-borne ozone observing systems. A meeting of selected scientists, that is those that took part in the actual intercomparison (Wallops island, Autumn 1979) was held in Saskatoon, Canada from 23-27 March 1981. The Study is progressing well and is expected to provide an assessment of historical rocket data. Also of relevance to this activity was the sponsoring of a Meeting of Experts on Ozone Photochemistry held in Boulder, USA also in March 1981.

Stratospheric assessment

166. Continuous activities carried out, in parallel, or directly under the World Plan and the WMO Ozone Project have generated a great deal of knowledge on the stratosphere and ozone. In view of this, WMO, with support from NASA, NOAA and UNEP organized a meeting of experts on the State of the Stratosphere-1981, whose purpose was to summarize all information available into a single document. The meeting was held at Hampton, Virginia, USA in May 1981. Some of the main conclusions of the meeting can be summarized as follows (paragraph 14-21).

167. In recent years, although the basic theory of stratospheric chemistry has not changed a great deal, advances in laboratory techniques have provided many new values of chemical reaction rate coefficients and their temperature and pressure dependencies. These determinations are subject to less uncertainty because in many instances the reaction products have now been directly observed, unlike the situation in the past. As a result, the chemical reaction rate coefficients for the reactions involving HO_x species have had to be revised (notably for $OH + HNO_3$, $OH + HO_2NO_2$ and $OH + HO_2$). The pressure dependence of the rate coefficient for $OH + HO_2$ is still a matter of debate. The major effect of these rate coefficient changes has been to change the vertical profile of ozone destruction and production. In the upper stratosphere ($\sim$40 km) they have had little impact on predicted ozone depletions due to increased Cl_x or NO_x - there the depletions are still large. However, in the lower stratosphere the impact has been great - most models now predict an increase in ozone in this layer due to CFC's emission with the net result of a greatly reduced overall percentage reduction of the total ozone column. As well the depletion/production of ozone due to increases in NO_x are critically dependent on altitude.

168. Model calculations using the revised chemical reaction rate coefficients indicate a reduction in the stratospheric ozone ranging from about 5 to 10 per cent at steady state for continued release of CFM's at the 1977 rate. Calculations using the same models indicate that large fleets of aircraft, whether supersonic or subsonic operating in or above lower stratospheric altitudes (15 km in the middle and polar latitudes in the current models) would significantly deplete the ozone layer; that fleets operating exclusively below such altitudes would cause some ozone increases. Thus the ozone change attributable solely to existing or planned fleets would depend upon their sizes and operating altitudes.

169. The comparison of model calculations with atmospheric observations of ClO shows that the previous discrepancy in the lower stratospheric altitudes has all but disappeared. However, the observations are about a factor of 2 larger than the model calculations near 40 km.

170. The continuing uncertainty in the reaction rate coefficient makes a direct measurement of OH in the 15-25 km range vitally important.

18. The roles of tropospheric-stratospheric transport and CH_4 oxidation in the stratospheric water vapour budget are still unresolved.

171. The range of available measurements, resulting from different techniques and lines and locations of observations, for other stratospheric trace species (e.g. NO, HNO_3, HCl) is such that these measurements do not provide sufficiently well defined distributions to validate the theoretical models. Clearly, there is a need to carry out further experimental programmes emphasizing in-situ simultaneous measurements of the key trace species.

172. The SBUV data for 1978-79 are reported to give ozone concentrations at 40 km about 5% less than BUV measurements in 1970-71. However detailed analysis has apparently revealed no statistically significant way to interpret this as a trend in upper stratospheric ozone over the decade. In general, individual scenarios for ozone change (e.g. CFMs) cannot at this time be tested for trends against the observations. In addition to natural atmospheric variability and observational deficiencies, the trend may be masked by a variety of possible alternative effects - tropospheric ozone increases due to combustion products (including aircraft emissions), stratospheric increases due to CO_2 cooling, solar variations in 11 year and 22 year range, etc. Hence, one finds that although there are only few positive model validations in terms of measured values and profiles of constituents, there is still no way using the available ozone data to statistically confirm or deny the existence of a small ozone trend component.

173. This leads to the conclusion that there is no scientific basis to reject the hypothesis that theoretical model predictions of ozone trends are consistent with the observational evidence and to the recognition that there is a threat of a considerable depletion of the ozone layer in the future. The prudent course of action would be to continue to step up efforts to reduce the scientific uncertainties.

174. The report from the meeting (~400 pages) is now being edited and will be issued in the WMO Ozone Project publications for wide distribution toward the end of 1981.

Other items

175. Final editing is in progress on a review entitled "Impact of Ozone and Other Atmospheric Minor Gases on Global Climate Changes" prepared by a group of Soviet scientists for the WMO Ozone Project.

176. Although the direct effect of a reduction in stratospheric ozone on global surface temperatures may be small (~0.1°C), other aspects render the ozone layer of importance in the climate problem. Among these are a surface warming component up to 1°C due to tropospheric ozone and the CFMs, dynamical changes in the stratosphere, aerosol effects and links to solar-terrestrial processes, all of which needs further detailed studies.

177. A review is nearing completion on "The use of satellites in ozone measurements, including data availability". The review is being performed by Dr. D. Heath (NASA).

178. Work is continuing on an extensive review on "Stratospheric circulation and ozone analysis". The work is being undertaken by Mr. F. Finger (USA) and Drs. R. Murgatroyd (UK) and R.D. Bojkov (WMO).

179. Publication is expected shortly of a report on ozone 2D modelling capability prepared by Dr. J. Chang (USA).

ACTION PROPOSED

180. The Co-ordinating Committee on the Ozone Layer is invited to note:

- The efforts made and the continuing need to support, maintain and upgrade the Global Ozone Observing System (GOOS), having regard to: Spectrophotometer networks (total ozone and Umkehr profiles); Satellite measurements (upper stratospheric values, particularly important for early trend detection); Ozonesondes (increased importance due to tropospheric and lower stratospheric projected increases);

- Improved information on reaction rate coefficients and continuing need to narrow uncertainty ranges;

- The need for more co-ordinated measurements of trace constituents with particular emphasis on ClO, OH, etc., and of solar radiation parameters;

- The requirement for improved two and three-D modelling with further emphasis on the troposphere and lower stratosphere;

- The latest figures for CFM ozone depletion - about 5 to 10 per cent reduction in total ozone at steady state.

Chemical Manufacturers Association

OZONE TREND ANALYSIS

181. The analyses of ground-based (Dobson) and satellite ozone data for trends by the two separate U.S. statistical groups funded by CMA show that during the period 1970-79 there was an increase in the column ozone concentration which however was not statistically significant. The two studies find an increase of 0.8 and 1.7 percent per decade. Using data from 36 Dobson stations, these groups have quantified the uncertainty in the detection of any long term trend regardless of cause to be ± 1.3 percent per decade in the first case and ± 2.0 percent in the second, expressing the uncertainty as 95 percent confidence limits. These numbers represent the combined error from instrument drifts, station-to-station variance, the white noise, and long-term trends that can be revealed by a 22-year data record. This error was previously estimated at ± 5.4 percent at the Harpers Ferry NASA Workshop (NASA Ref. Publication 1049, Tab 6.13, p. 325, Dec. 1979). The 1981 WMO/NASA Workshop presents an estimated range for this uncertainty of 1.6 percent to 3.8 percent (preliminary draft).

182. Because the Dobson stations are land-based and concentrated in the Northern Hemisphere, it has been suggested that the trend estimated from the 36 stations may not represent the true global trend. Satellite data from Nimbus IV over the period 1970-77 have been examined, and it has been shown that the difference between the trend derived from the global satellite ozone data and that derived from the satellite ozone data above the 36 stations studied is small. Hence, there is no statistically significant spatial sampling bias according to this analysis.

183. The sensitivity of the ozone trend analysis results to the effects of nuclear testing in the 1960's has been examined. According to theory, the extent of the depletion of stratospheric ozone due to the injection of large quantities of NO_x into the stratosphere at that time should have reached a maximum of 2-4 percent, followed by recovery to equilibrium levels. The trend estimate and trend precision for ozone change during the 1970's are essentially unaltered by the inclusion of the effects of nuclear testing.

184. Associated work by two participating member companies of the CMA Fluorocarbon Program Panel have confirmed the above conclusions drawn from the Dobson station column data. In addition, a detailed study of the Dobson station data from Arosa extending over 48 years has been made. This work has produced threshold limits for the detection of an effect due to CFC release of $\pm$ 2-3 percent per decade. This figure can be compared with the 1979 estimates of 5 percent in the NAS report and 5.7 percent in NASA 1049.

185. Statistical analysis of the 33-48 km Umkehr data from 15 Dobson stations with more than 50 observations, showed a statistically insignificant increase over the period 1970-79. These results suggest that ozone depletion has not occurred in the region of the stratosphere calculated to be most sensitive to CFC effects.

186. In support of the conclusion that no depletion of ozone has so far occurred, measurements of sunburn units, essentially equivalent to the erythema action spectrum (EAS), at various locations from 1974 to 1979, have shown no increase in intensity. If the amplification factor relating changes in ozone to changes in incident EAS radiation is correct then the changes in sunburn units should be a sensitive indicator of ozone changes.

ATMOSPHERIC MEASUREMENTS

187. The emphasis of the measurement program has continued to be on ground-based measurements, which produce a large number of measurements of a stratospheric species over a long period of time, rather than the isolated measurements over a few hours from in situ methods. Data on column ClO from measurements made in Massachusetts in 1980 have been published, showing results consistent with Anderson's balloon measurements. The winter measurement program in Massachusetts in 1981 yielded only a few measurements due to the high water vapor levels in the mild winter, but the equipment has been operated successfully at Mt. Hopkins observatory near Tucson, Arizona, for a 4-week period. The data are expected to characterize the atmospheric variability of ClO and the diurnal cycle, as well as yielding an intercomparison with Waters' balloon-borne ClO measurement program.

188. Tropospheric measurements other than ALE continue (see following section). In a preliminary study, measured values of CFC-21 in the Red Sea and Indian Ocean were considerably elevated over the background 1 ppt level, and it is speculated that this may be the result of decomposition of CFC-11 on sand. An experiment is in progress to test this hypothesis by sampling an air parcel as it enters the desert area and again several hundred kilometers downwind. The samples will be analyzed for CFC-11 and CFC-21 to determine if CFC-11 concentrations are reduced during passage over the desert and if corresponding amounts of CFC-21 are formed.

189. Further data reduction from the National Physical Laboratory/University of Florence flight from Texas in April 1979, a program to make aircraft-borne ClO measurements, and an international data analysis program between the University of Denver and the University of Reims are in progress. A balloon

flight is planned to determine the concentration of $ClONO_2$ by several techniques simultaneously, and to search for HOCl and HO_2NO_2. An IR measurement balloon is also planned in conjunction with Anderson's reel-down experiment, presently scheduled for spring 1982.

190. Method development has continued to be given considerable support.

. A UV method for ClO measurement is nearing completion.

. A simple method for measuring methyl chloride in ambient air and in river or sea waters has been completed.

A new technique for accurately measuring N_2O in the atmosphere using a tunable diode laser has been developed.

A flow system using Laser Magnetic Resonance detection for measuring the rate constants of important reactions at pressures and temperatures corresponding to those actually present in the stratosphere has been built.

An evaluation is being made of the application to other species of the ground-based microwave technique now being used successfully and routinely for ClO and for the simultaneous measurement of ClO and O_3.

. Studies are in progress to record the far-infrared laboratory spectra of a number of molecules of interest in current stratospheric chemistry, in particular the spectrum of HOCl. The apparatus can be flown on a balloon for stratospheric measurements.

191. A study to measure total chlorine in air by passage of the sample through a microwave discharge followed by measurement of chlorine resonance lines showed the sensitivity of the method was not sufficient to permit total chlorine analysis of stratospheric air samples.

ATMOSPHERIC LIFETIME EXPERIMENT (ALE)

192. Preliminary results from two years' data indicate an atmospheric lifetime for CFC-11 of roughly one half of the currently calculated lifetime (75 years) due to the stratospheric removal process alone. The error bars in the observed lifetime are, however, still large - of the order of 15 years to infinity. Three years of data will provide a much firmer estimate.

193. Computer models, in contrast to this real world experiment, contain the assumption that there is no destruction of CFC-11 or CFC-12 other than by stratospheric processes. If lifetimes one half of those now assumed are considered, the calculated steady state ozone depletion would be reduced by 50 percent.

194. The four original ALE monitoring stations have now been in operation for over 36 months and performance continues at a high level. Calibration checks have been completed on the first 30 months data. A fifth station on the Oregon Coast (Northwest USA) has been in operation since March 1980. The data record at this station for CFC-11 has been obtained from parallel equipment since 1979, augmenting the data in the important northern hemisphere temperate zone.

195. Work using an exponential dilution chamber has been completed to supplement the data on the absolute calibration of the ALE network standards. In addition, a coulometric technique has been used to provide a further absolute calibration value. The three independent calibrations of the reference standards agree with each other to within a few percent.

CFC-11 AND CFC-12 PRODUCTION

196. Production and release data for CFC-11 and CFC-12 have again been collected from the world CFC manufacturers and the data submitted separately to UNEP. These figures show that world CFC production peaked in 1974 and that the 1980 production was 18.1 percent below the 1974 level.

ATMOSPHERIC CHEMISTRY

197. The industry program to elucidate stratospheric chemistry centers on species and reactions likely to affect the chlorofluorocarbon/ozone depletion theory, e.g. Cl, ClO, higher chlorine oxides, $ClONO_2$, HOCl, OH, and HO_2, and on reactions that might constitute ozone production cycles. The pressure and temperature dependences and product distributions of important reactions have received increased emphasis recently.

198. Much of the work is concentrated on examination of the products produced from stratospheric reactions. The disappearance of reactants is well characterized for many of these systems, but a single product path has often been assumed. These studies include:

$ClO + NO_2$ where isomers of $ClONO_2$ are being sought.

$Cl + O_3$ where excited singlet O_2 ($^1\Delta_g$, $^1\Sigma^+_g$), which can react with O_3 to produce O atoms, has been observed (although this observation is unlikely to be of great importance in the stratosphere).

$HO_2 + Cl$ where $HCl + O_2$ is the major product, but $OH + ClO$ is not insignificant.

$HO_2 + ClO$ where one investigator has set an upper limit of 2 percent for the $HCl + O_3$ branch.

. OH + ClO where the HOCl + O and HCl + O_2 minor branches are being sought.

. Cl + HOCl.

199. Reaction rates for $HO_2 + HO_2$, $OH + HO_2NO_2$, $OH + HO_2$, $OH + HNO_3$, and $HO_2 + Cl$ are currently under investigation in the important area of HO_x chemistry. Atmospheric observations, particularly of ClO profiles, indicate that OH concentration in the lower stratosphere is considerably less than has been calculated by the theoretical models. Although agreement is much improved with the latest chemistry, considerable uncertainty still surrounds the OH chemistry in this region. Study of the above important reactions has been undertaken to try to resolve this question.

200. Sources of odd oxygen are being explored by study of the reactions $Cl + O_3$, Cl + ClOCl, Cl + OClO, and the photolysis of HOCl, ClOO, and OClOO.

201. A two-day chemistry workshop was held in March, bringing together a large number of eminent kineticists to discuss the current uncertainties in stratospheric chemistry. A report on this workshop is available from CMA.

MODELING

202. Emphasis by the two CMA FPP-supported modeling groups is now being placed on 2-D models. Major conclusions from this work are given below. It should be noted that improved knowledge of the chemistry during the last year has considerably reduced the calculated steady-state ozone depletion potential of CFCs. This underlines the uncertainties associated with the model calculations and illustrates the danger of drawing firm conclusions from them.

203. A present-day (1980) depletion of 0.6 percent is indicated by 1-D model calculations based on historical release of CFCs. Continued emissions at the 1977 production levels are calculated to give 1.2 percent depletion by 1990, increasing to 1.7 percent in the year 2000. Continued release of CFCs gives an ultimate calculated reduction in global average ozone of 6.1 percent at steady state. This compares with 10 percent in the UNEP-CCOL 1980 report and 15 percent in the UNEP-CCOL 1979 report.

204. These values have been calculated with a slower rate of formation of chlorine nitrate relative to previous recommendations. If the fast formation rate (included within the specified uncertainty in current recommendations) is used, steady state depletions of about 5.0 percent are calculated. The correct rate of formation of chlorine nitrate is still unresolved.

205. Recent changes in the chemistry used for model calculations mean that there is no longer a prediction of much greater depletion at high latitudes than at low latitudes. Although there is still a somewhat greater depletion at the North Pole than at the equator in current calculations, the difference is now only about 20 percent.

206. Another shift in the location of ozone depletion has occurred in the vertical dimension. The high depletion formerly calculated in the lower stratosphere has virtually disappeared, so that most ozone depletion is now calculated (as it once was) to occur above 30 kilometers. Both 1-D and 2-D results indicate a net increase in ozone due to chlorine in the lower stratosphere (primarily in tropical regions in the 2-D model).

207. The chemical reactions have been considered to be the best known and firmest of the model input data, yet surprising and dramatic changes in chemistry have produced significantly lower values and different distributions of ozone depletion than those calculated in 1979. Considerable uncertainty still remains throughout the chemical scheme.

RESEARCH UNDER CONSIDERATION

208. The CMA program of research in chemistry, modeling, and measurements is continuing through 1982.

Specific new research projects being considered include:

- automation of Dobson stations to facilitate Umkehr measurements.
- cofunding with NASA and other groups of balloon flights for the intercomparison of various techniques for measuring HCl in the stratosphere.
- investigation of the proposed complex of ClO with oxygen, namely $ClO.O_2$.

ANNEX 4

CCOL V CONTRIBUTION TO THE AD HOC WORKING GROUP OF LEGAL AND TECHNICAL EXPERTS TO ELABORATE A GLOBAL FRAMEWORK CONVENTION FOR THE PROTECTION OF THE OZONE LAYER

1. In accordance with Decision 9/13B of the Governing Council of UNEP on the Protection of the Ozone Layer, wherein it is stated that the Co-ordinating Committee on the Ozone Layer (CCOL) is invited, as part of its activities under its mandate, to contribute to the work of the Ad Hoc Working Group of Legal and Technical Experts - the CCOL wishes to submit to the Ad Hoc Working Group the Report of its 5th Session. The CCOL wishes, in particular, to draw attention to its statement therein on:

i) the status of the ozone layer,
ii) monitoring,
iii modelling results,
iv) the assessment of UV-B effects,
v) production, usage and emissions of ozone-affecting chemicals other than CFC-11 and CFC-12, and
vi) possible influences on climate.

2. In addition, the CCOL wishes to bring to the attention of the Ad Hoc Working Group the importance of considering, during its own deliberation on a global framework convention on the protection of the ozone layer, the following aspects:

a) Monitoring of:
   i) the status of the ozone layer,
   ii) UV-B irradiance,
   iii) the global production, release and use of ozone-affecting substances, and
   iv) the content of trace constituents of the atmosphere which may affect the ozone layer.

b) Research on:
   i) the trace constituents of the troposphere and stratosphere,
   ii) the chemistry and dynamics of the stratosphere,
   iii) the biological effects of UV-B radiation,
   iv) computational models of the atmosphere, and
   v) the validation of such models.

c) The Use of Models to calculate:

i) the future change of the ozone layer,

ii) the consequent changes of UV-B radiation, and

iii) the impact on climate.

d) Assessment of:

i) the status of the ozone layer,

ii) the impact of predicted changes of UV-B radiation, and

iii) the socio-economic impact of alternative control strategies.

e) Development of:

i) best available and economically feasible technologies to limit/reduce emissions of ozone-affecting substances, and

ii) alternative chemicals/techniques/products to replace those regulated by controls.

3. The Co-ordinating Committee on the Ozone Layer wishes to inform the Ad Hoc Working Group that it has a capability to advise the Working Group on, and is prepared further to assist it with respect to the majority of those areas under section 2. The following are aspects on which the CCOL has not carried out any work, but which it considers to be of relevance to the deliberations of the Ad Hoc Working Group:

a) Socio-Economic Impact of Alternative Control Strategies - although reference to this topic is contained in the World Plan of Action, to date there has not been a comprehensive study of this matter apart from individual studies on specific aspects carried out by member countries and in the EEC which can be made available to the Ad Hoc Working Group.

c) Development of:

i) best available and economically feasible technologies to limit/reduce emissions of ozone-affecting substances.

4. The Committee recommends that the Secretariat:

i) contacts member countries to make available recent model scenario reports to the Ad Hoc Working Group.

ii) makes available for the Ad Hoc Working Group meeting in January, other material on relevant work on other fora.

iii) makes available to the Ad Hoc Working Group relevant information, including statistical and technical data, on the implementation of the recommendations contained in Decision 8/7B of 29 April 1980.

ANNEX 5

EXECUTIVE SUMMARY

The United Nations Environment Programme's Co-ordinating Committee on the Ozone Layer (CCOL) met in Copenhagen 12-16 October 1981 for its fifth session. The Committee examined the substantial contributions presented to it by various countries and organizations and the research efforts in observations, evaluations and modelling necessary for the study of the stratosphere. On the basis of existing and new information available the Committee concluded the following:

1. A risk of depletion of the ozone layer due to chlorofluorocarbon releases is still most likely, although natural variations and other compounds which may effect ozone, require increased consideration.

2. If one considers only chlorofluorocarbon 11 and 12 releases at their present rates, current model calculations estimate an eventual ozone reduction in the range 5 to 10 per cent, compared to about 10 per cent estimated in last year's CCOL report. The change from the 1980 figure is due to new data on certain chemical reaction rates. If present releases of other chlorocarbons are continued at present rates, then they could increase the eventual ozone depletion due to CFC 11 and 12 alone by about one third.

3. Recognizing the simultaneous and complex impacts of human activities on atmospheric ozone, more realistic scenarios have been developed to study the coupled nature of potential ozone changes. The changes in the trace gas concentrations of N_2O, NO_x and CFC's may have all affected the past ozone amounts. The estimate of the present total column ozone depletion is less than one per cent, which is below the present detection limit.

4. The relatively large natural variability of atmospheric ozone makes detection of long-term trend difficult. Consistent with the study using multiple scenarios from historical data, no evidence of changes in total ozone has been observed. This recognises the significant continuing progress made in statistical analysis of the ozone record.

5. Observational data indicate an ozone increase in the northern hemisphere troposphere over the last 10 years which is qualitatively consistent with the model predicted impact from past subsonic aircraft operations and other combustions. Observations in the upper stratosphere are still inadequate to validate the model predicted changes due to CFC 11 and 12 releases in the past decades. Multiple scenario models suggest that the distortion of the vertical ozone profile might become more important than changes in the total amount with respect to possible climatic consequences.

6. Continued improvement of the data base or atmospheric trace species has contributed to the resolution of some past problems in interpretation and pointed out new areas of possible concern.

7. World production of CFC's 11 and 12 combined as estimated by the Chemical Manufacturer's Association has fallen by a total of 18% between 1974 and 1980. Most of the decrease occurred in the years 1974 to 1977; only 1% decrease took place in the past year (1980). Uses in aerosols have declined but other uses, for example in foamed plastics and air conditioners, have shown an increase. It is recognized that eventually reduction of CFC used in aerosols could be offset by growth in non-aerosol uses. There are also indications of increased production of other chlorine containing compounds which could affect the ozone layer.

8. If atmospheric ozone decreases, more solar ultraviolet radiation, in the UV-B range, will penetrate to the earth's surface. New studies have confirmed previous estimates of the relation between ozone decrease and UV-B increase. The health and biological effects to be expected from such an increase of ultraviolet radiation formed one of the main topics of discussion at the meeting. Most of the known effects of UV-B are damaging effects, so that there is concern for the consequences, especially with regard to agricultural production, fisheries and human health.

9. Recent research results indicate that many terrestrial plants and aquatic organisms may undergo damage by increased UV-B; this applies to important crops such as wheat and rice, and to aquatic organisms such as fish eggs and larvae. Further investigations are needed, however, to assess the overall effects under the complicated actual growth conditions.

10. With regard to human health, it is well-established that an increase in solar UV-B would lead to an increased incidence of non-melanoma skin cancer, especially in light-skinned people.

There are several indications that sunlight may be one of the causative factors of malignant melanoma, which affects people of all skin types. It is presently not known if UV-B is involved; should it be involved, a decrease of atmospheric ozone might be expected to increase the incidence of melanoma.

11. The committee emphasized the importance of member countries and international organizations as WMO, with the support of UNEP to provide pertinent chemical production, release, and usage data and to continue to collaborate in studies on the ozone layer.